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Physical Therapist Students' Development of Diagnostic Reasoning: A Longitudinal Study

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Physical Therapist Students' Development of Diagnostic Reasoning: A Longitudinal Study

Sarah Gilliland, PT, DPT, PhD

Background and Purpose. Clinical reasoning is a complex problem-solving process that is necessary for effective clinical practice in physical therapy. Within the process of clinical reasoning, a physical therapist's diagnostic reasoning should address the patient's functional movement abilities and the impact of the patient's condition on his or her ability to participate in life activities. This longitudinal study examined the development of entry-level physical therapist students' diagnostic reasoning processes across time in their doctor of physical therapy education.

Methods. Qualitative methods were used to analyze participants' diagnostic reasoning during a simulated patient case scenario. Six physical therapist students completed a think-aloud patient case scenario at 3 points during their entry-level education (first-year, second-year, and postclinical). Low-inference data (verbatim transcripts) from the students' think-aloud work on the patient cases and postcase interviews were analyzed using a 2-stage process of thematic analysis. Structural coding was followed by pattern coding to categorize students' diagnostic reasoning processes.

Results. Students' hypotheses focused on anatomical structures during their first year and shifted to medical diagnoses and biomechanical contributing factors during the second year and following clinical affiliation. Students consistently focused on the anatomical and biomechanical (impairment level) aspects of the patient's condition and gave minimal attention the patient's life context (participation level).

Discussion and Conclusion. Students demonstrated consistent development toward the movement and biomechanical elements of the specific physical therapist diagnostic process, yet they demonstrated no consistent patterns of development toward identifying or addressing the impact of the patient's life context on his or her level of disability. Further research should examine the curricular factors that influence students' patterns of development in diagnostic reasoning.

Key Words: Clinical reasoning, Entry-level physical therapist education, Student learning.

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BACKGROUND AND PURPOSE

Clinical reasoning is a complex problem-framing, problem-solving, and decision-making process. This process is highly dependent on context, requires interaction with the patient, caregivers, and other health-care team members, and is influenced by models of practice.[1] Additionally, this iterative process requires clinicians to make decisions and continually reassess actions taken in the face of uncertainty.[1] To function as autonomous professionals, physical therapists (PTs) must develop effective clinical reasoning skills.[2,3]

Few studies, however, have investigated the development of clinical reasoning skills in PT students. Further, there is a dearth of evidence for benchmarks or assessments of clinical reasoning development in entry-level PT education.[4,5] Instruction during residency and fellowship programs has given more explicit attention to the development of clinical reasoning and metacognitive skills, but this level of attention is not the norm in entry-level programs.[4] The literature further suggests that there may be a disconnect between students' development and the thinking processes of accomplished clinicians.[6] In part this minimal attention to clinical reasoning in entry-level development may be due to a lack of research regarding how best to develop these skills.[5]

One of the first steps toward developing better-informed pedagogies and assessments for clinical reasoning skills is to examine how entry-level PT students currently approach clinical problem solving. This study examined how entry-level PT students develop physical therapy-specific diagnostic reasoning through their coursework and initial clinical affiliations. The primary research questions were: (1) What types of hypotheses and evaluations do PT students make when they evaluate a patient? (2) What reasoning errors do PT students make during the patient evaluation? and (3) How do the hypotheses PT students generate change following classroom coursework and clinical affiliations?

REVIEW OF THE LITERATURE

Diagnostic Reasoning as Part of Clinical Reasoning

Clinical reasoning in expert practitioners entails a complex interweaving of empirico-deductive and narrative reasoning.[7] Diagnostic reasoning, a critical skill within clinical reasoning, is a clinical classification process that involves relating the patient's level of disability with his or her physical function and pathology.[8,9] Through the diagnostic process, the clinician develops an understanding of the patient and his or her problems.[10] In all health care practices, the diagnostic process directs the clinician toward the selection of appropriate interventions.[11] For a PT, the diagnosis of pathology (defined as the name given to a cluster of signs and symptoms) does not always explain the underlying nature or cause of the patient's physical function or disability.[11] For these reasons, the diagnostic process must be unique to the specific health care field.

Physical Therapy-Specific Diagnosis

Specific to physical therapist practice, diagnostic reasoning requires clinicians to integrate their analyses of the patient's health condition and biomechanical fault with an understanding of the impact of the impairments on the patient's ability to function in daily life.[10] The PT's diagnosis generally addresses the patient's condition at the level of the whole person and should categorize the condition in a way that will guide the PT's treatment plan.[12] The literature on diagnosis by physical therapists identifies 3 key elements of the physical therapist diagnostic process. First, the PT must identify movement-related dysfunction.[9] This process includes identifying movement impairments and their relation to the patient's physical function.[13] Second, the diagnosis must direct physical therapist treatment.[11] A medical diagnosis alone is not sufficient to identify the most effective physical therapist interventions.[11] Through the diagnostic process, PTs must also identify factors that contribute to the patient's problem,[14] as these factors often become the focal point for treatment. Third, the PT must develop an understanding of how the patient's personal characteristics and disease process affect his or her level of disability.[13,15] Expert PTs give significant attention to understanding their patients' environments, life activities, and values.[16] To address the impact of the patient's condition on the whole person, a PT must obtain information from the patient interview relating to the impact of the individual's current condition on his or her life roles.[14] Developing a diagnosis including these 3 elements enables the PT to best address the movement and functional limitations that impact the patient's life.

The Role of Hypotheses in Diagnostic Reasoning

During the diagnostic process, health care practitioners develop hypotheses to guide their examination and problem-solving.[17] A hypothesis is any diagnostic idea[17] and may identify a health condition, an impairment, an activity limitation, or factors influencing the patient's participation.[14] Hypotheses are the practitioner's clinical impressions as to why the patient is not able to carry out desired activities,[18] and they include ideas about why the problems exist.[14] The hypotheses shape the types of data collected during the patient examination,[14] represent the clinician's unfolding diagnostic process, and eventually guide the development of treatment.[18] The hypotheses formed during the diagnostic process also influence the criteria a clinician selects to evaluate the effectiveness of the treatment.[14]

Table 1. Coursework Completed at Each Phase of the Study

	Courses Completed	Relevance to Reasoning
First Year (Second Semester)	• Basic sciences (anatomy, physiology, biomechanics) • General pathology	• Currently enrolled in orthopedic pathology and physical therapist examination courses (introduction to the basic process of patient examination) • Introduced to general tissue pathology (bone, joint, muscle, ligament) but not specific diagnoses
Second Year (Fourth Semester)	• All basic and applied science courses • All orthopedic and neurologic pathology and clinical practice courses • Cultural diversity and motor learning • 2 2-week preclinical field experiences	• Extensive classroom experience with clinical problem solving but minimal field experience
Postclinic (Fifth Semester)	• 12-16 weeks of clinical affiliations	• Practical clinical experience in addition to classroom instruction in clinical problem solving and patient care

An analysis of the types of hypotheses a clinician or health care student makes during a patient evaluation can provide insight into his or her diagnostic reasoning process. Most medical reasoning studies have focused on the diagnostic process at the level of the health condition (medical diagnosis).[19-22] These studies revealed that over the course of their education, medical students tend to shift from a focus on basic science concepts to one of medical diagnoses in their generation of hypotheses.[23] Through their education, PT students should progress toward physical therapy-specific diagnostic reasoning processes. No studies to date, however, have examined the development of PT students' diagnostic reasoning processes. Through an analysis of their hypotheses and patient evaluations, this qualitative study examined how PT students' diagnostic reasoning processes develop through their coursework and clinical experiences.

Subjects

This study took place in the doctor of physical therapy program at a small private western university in the United States. All participants provided signed informed consent prior to participation. Given the aim of longitudinally examining the students' development of clinical reasoning skills, a random sample of 6 student volunteers was selected from the first-year class at the beginning of their second semester of course work. To ensure data saturation, an additional 2 students completed the case scenario and interview during their first year. Analyses of these additional cases indicated reasoning patterns present within the first 6 participants, and thus the additional 2 were not included in the longitudinal component of the study. The timing of the first data-collection session allowed for initial assessment of the first-year students at a point in their education when they had completed their foundational basic sciences but had only a brief introduction to clinical problem solving. The same assessment procedures were then repeated at the completion of the students' fourth semester (completion of clinical didactic coursework) and their fifth semester full-time clinical affiliation. Table 1 summarizes the timing of the study with respect to the students' education. The primary researcher was a faculty member in the program; however, she did not teach the students involved in this study, nor did she teach any of the clinical courses related to the activities in this study.

Due to the class demographics, random selection, and the small sample size, all students were female. The students' mean age

Table 2. Participant Background Information

Pseudonym	Age (at first year)	Prior Clinical Experience	Full-Time Clinical Affiliation
Shelly	24	• 360 hours total • Aide in orthopedic clinic (1 yr) • Hospital outpatient clinic • Inpatient (1 day)	• Inpatient acute care
Misty	22	• 200 hrs total • Outpatient neurologic (40 hrs) • Acute (8 hrs)	• Outpatient orthopedic • Inpatient acute care
Maya	23	• Aide in outpatient orthopedic w/ aquatic therapy (1.5 yrs) • Acute (1 day)	• Outpatient orthopedic
Jenn	25	• Aide in outpatient orthopedic w/ geriatrics and pediatrics (3 yrs) • Hospital volunteer in NICU and some adult	• Inpatient acute care • Outpatient orthopedic
Kelly	23	• Outpatient orthopedic (private practice) • 1 day neurologic clinic	• Inpatient rehabilitation
Cathy	22	• 3 months 3 days/wk observing outpatient orthopedic • Athletic training	• Outpatient orthopedic

was 23.4 years at the time of the initial data collection. At the time of the first data collection session, all students had experience volunteering or working as aides in outpatient orthopedic clinics; none had been athletic trainers or physical therapist assistants prior to enrolling in the program. Table 2 summarizes the students' clinical experiences prior to and during the course of the study. To protect students' identities, each was assigned a pseudonym for the study.

METHODS

Overview of Methods

A clinical role-play of a patient case scenario was used to assess students' approaches to diagnostic reasoning.[24] This study builds on a cross-sectional analysis of clinical reasoning in first- and third-year PT students that includes a full explanation of the rationale for the method.[25] For the student population in this study, the verbal exchange approach to patient simulation used by James[24] was preferable to a patient simulation approach in which the student actually performs the manual tests on an actor[26], because the initial data collection was being performed before the students had been introduced to hands-on clinical skills. Additionally, the information-focused format allowed for assessment of the students' problem-solving approaches without confounding by their limited technical skills.

A different patient case scenario was used for each assessment, but all patient cases exhibited "typical" presentations for their orthopedic diagnosis (see Appendix 1 for case descriptions). The cases were reviewed by practicing PTs (2–12 years of experience) who served as offsite clinical instructors for the program to ensure an equivalent level of diagnostic difficulty for the 3 cases. Each case included details of the patient's life context.

Data Collection

The following procedures were repeated for the initial assessment and each follow-up using a different patient case for each follow-up (see Appendix 1 for patient case descriptions). The researcher met with each student individually in a quiet room. The student practiced a think-aloud task prior to the case scenario role-play. The researcher then gave the student a brief description of the patient, including the patient's age, sex, and location of pain. The student was instructed to ask the researcher questions about the patient based on the elements of physical therapist examination (eg, aggravating factors, lifestyle, range of motion, strength) as if he or she were evaluating the patient in a clinic. The researcher read aloud from the written case description in response to the student's questions regarding both subjective and objective examination data. In addition to thinking out loud throughout the process,[27-29] students were allowed to write down their findings to help them remember and organize their thought processes; however, they were not given any specifications about what to write down. When the students had gathered as much information as they wanted about the patient, they made their evaluations. Throughout the think-aloud process, the researcher took notes on the type of information the students acquired, how they ordered that information, and the hypotheses formed.

Immediately following the think-aloud task, the researcher used her notes to guide the interview regarding each student's process through the patient case (a retrospective think-aloud). The retrospective think-aloud provided student with the opportunity to confirm or clarify the hypotheses they had stated during the concurrent think-aloud case scenario. The think-aloud process and interviews were audiotaped and transcribed, and all student notes completed during the diagnostic and treatment-planning processes were collected for analysis (see Appendix 2).

Data Analysis

A 2-stage iterative process based on thematic analysis was used to code and analyze the research questions.[30] Thematic analysis differs from grounded theory in that for thematic inquiry the initial coding categories are derived from existing theory, whereas grounded theory builds coding categories from the data.[31] In the first stage, structural coding[32] was used to identify the information the students gathered and the types of hypotheses and evaluations they made. Structural coding allows selection of a coding frame that matches the theoretical framework of the study.[32] Because this study involved the role of hypotheses in PTs' diagnostic reasoning, the structural coding drew on existing literature of hypotheses and examination processes in physical

Table 3. Hypotheses and Evaluations[a]

Code[b]	Definition
Health Condition	**Health conditions** include diseases, disorders, and injuries.
Anatomical Structure[c]	**Body structures** include anatomical parts of the body such as bones, joints, muscles, and their components.
Body Function/ Impairment	**Body functions** are physiological or biomechanical functions of body systems.
Activity	**Activity** includes the execution of a task by an individual.
Participation	**Participation** is involvement in a life situation.
Phase[c]	**Stage of healing** includes inflammatory, fibroblastic, and remodeling phases.
Mechanism of Injury[c]	**Mechanism of injury** includes overuse, acute, and systemic injury.
Causal/ Contributing	The named hypothesis **explains the underlying cause(s)** of the injury.
Causal Function	**Body function** (usually biomechanical) is identified not as the primary injury but **explaining the underlying cause** of the injury.
Patient Impact	**Patient impact** identifies how the health condition is affecting the patient's life experience.
Rule-Out[c]	The named hypothesis is no longer being considered.
Structure Rule-Out	The named body structure is no longer being considered.

[a]For the final evaluation, the modifier *Incorrect* was added if the participant named an incorrect structure, health condition, or phase of healing.
[b]Codes are derived from Jones et al.[10]
[c]These codes are not directly identified in Jones et al.[10]

Table 4. Reasoning Strategies for Patient Evaluation

Code	Definition
Trial and Error	No hypothesis or plan from beginning; moving from 1 structure to another with no clear line of reasoning
Following Protocol	Trying to remember exam forms from clinic or class
Rule-in/Rule-out	Beginning with 1 or more hypotheses; testing to include or exclude, then moving to next hypothesis; rudimentary version of hypothetico-deductive process
Hypothetico-Deductive	Generating hypotheses and using organized plan of testing to rule out or rule in; able to shift hypotheses if data conflict with primary hypothesis
Reasoning about Pain	Using the description of the pain and aggravating factors to guide reasoning; focused on biomedical aspects with considerations of chronicity and severity/irritability[a]

[a]Derived from Smart and Doody's[38] biomedical considerations of pain.

therapy. The second stage of analysis involved comparing the information the students collected with hypotheses they formed to identify reasoning patterns and errors.

Information Collected and Hypotheses. In the first stage, structural coding[32] was used to code all information sought by the student based on the categories of tests and measures defined in the *Guide to Physical Therapist Practice.*[33] Information collected in the following categories was considered the patient's personal characteristics: goal for physical therapy, occupation, recreational activities or hobbies, current functional status, living situation, and social history. Each student's statements of diagnostic ideas, contributing factors, and judgments were then coded as hypotheses[10,17] The coding categories for the hypotheses were derived from Jones et al.[10(p253)] Additional codes were added based on categories evident in data that were not represented in the original literature, using an iterative process. For example, the students frequently formed hypotheses about anatomical structures, a category not included in the Jones et al[10] original list. (See Table 3 for codes and definitions.) Additionally, each student's final evaluation of the patient was coded using the same system. This first stage of analysis was noncomparative, and the findings reported what types of hypotheses and evaluations the students made, regardless of their accuracy or appropriateness.

Evaluation strategy. Each student's strategy for approaching the patient examination and evaluation was assessed based on the patterns of information collected and hypotheses considered (ie, pattern coding[32]). Prior literature on medical reasoning[34,35] and clinical reasoning in physical therapy were considered in identifying the strategies.[36-38] Table 4 summarizes the codes applied to the reasoning strategies for patient evaluation. These codes include reasoning strategies previously described in the literature, with the addition of the emergent pattern "rule-in rule-out," a rudimentary version of the hypothetico-deductive process.

Table 5. Analytical Reasoning Errors

Code	Definition
Jumping to Conclusions	Taking 1 piece of information that was necessary but not sufficient to draw a certain conclusion, and "jumping" to that evaluation without considering the other findings necessary for drawing that conclusion
Perseveration	Taking a necessary but not sufficient piece of diagnostic information to rule in a particular hypothesis, and then continuing to rationalize that hypothesis as other information was collected, even when it ran counter to the participant's conclusion
Disregard	Ignoring unfamiliar information and moving on because of uncertainty concerning how to assess the unfamiliar information

Reasoning errors. To assess errors in the students' reasoning processes, the relationship between the examination information the student collected and the hypotheses they formed was examined. Statements the students made during the think-aloud sessions were categorized as reasoning errors if the students interpreted information incorrectly or drew conclusions not supported by the information they had collected. Each statement was examined for the type of error. (See Table 5.)

Credibility and trustworthiness. To triangulate across data collection methods[39,40] (concurrent think-aloud problem solving, retrospective think-aloud interview, and student notes), the students' process through the think-aloud was compared with their retrospective description of the case during the interview and the notes they had taken during the patient case problem. This information was analyzed for any discrepancies between data sources. The retrospective think-aloud further provided students an opportunity to confirm or clarify their reasoning processes as they reviewed the case with the researcher. To enhance the credibility and consistency of these findings, a random subsample of the data was coded by a second coder trained on the structural coding system.[41] The primary investigator and the second coder achieved agreement ranging from 73% (kappa 0.69) to 97% (kappa .95) across the structural coding categories. The coding category for hypotheses had the lowest initial agreement. This initial coding was followed by clarification of the definitions of each hypothesis code as well as clarification of the application of multiple codes to a single text selection. The researcher also maintained a document of memos throughout the data collection, coding, and analysis stages.[42] The researcher continually referred back to prior memos to assess the evolution of her analysis and to look for continuity or disconfirming evidence with prior stages of analysis.

RESULTS

Information Collected

The nature of the information the students collected about their patients changed over the 3 phases of the study. Students consistently acquired information about their patients regarding the patient's level and nature of pain during examination procedures. Following their clinical coursework and again after their clinical affiliations, students consistently conducted tests and measures typical of the physical therapist examination process,[33] including tests of range of motion, muscle performance, joint mobility, tissue integrity, and postural alignment. Through all phases of the study, the students demonstrated no consistent pattern as to whether or not they sought assessment of the patient's performance of functional activities such as gait, reaching, or stepping (Figure 1).

The students did not demonstrate a consistent pattern of change in their patient interview processes (Figure 2). They consistently gave attention to the biomedical aspects of the patients' pain reports, including the description and location of the pain, and aggravating and easing factors. Students did not consistently address any other aspects of the patient interview. During all phases of the study, students gave minimal attention to the information classified as patient personal information that was necessary to understand the impact of the injury on the patient's

Figure 1. Examination Data Obtained by Students

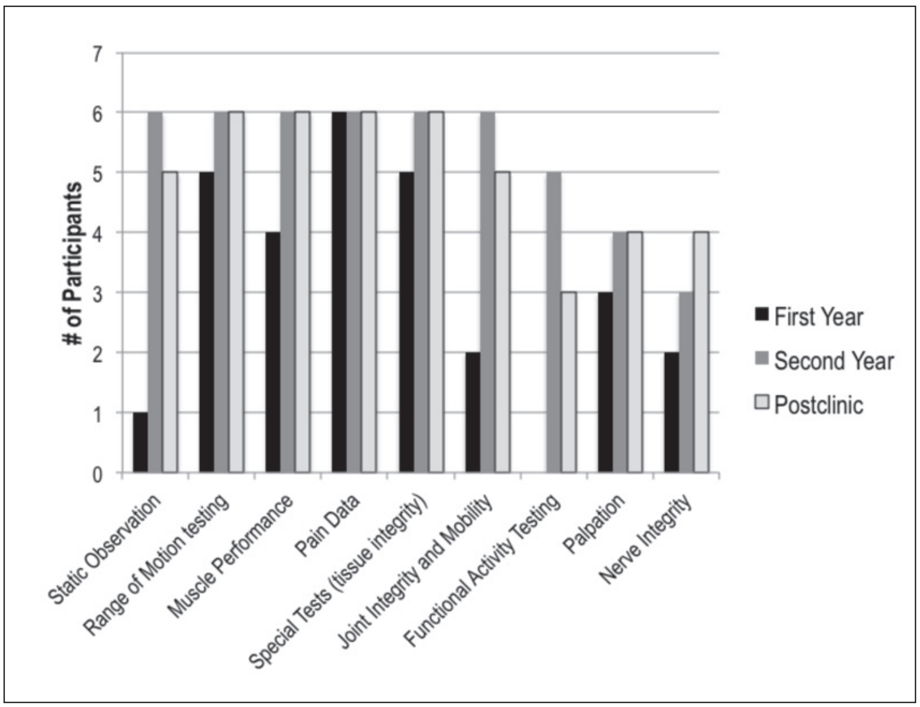

Figure 1 depicts the number of participants who conducted each type of examination test or measure at each phase of the study. Data categories are derived from *Guide to Physical Therapist Practice* 3.0.

Figure 2. Interview Data Obtained by Students

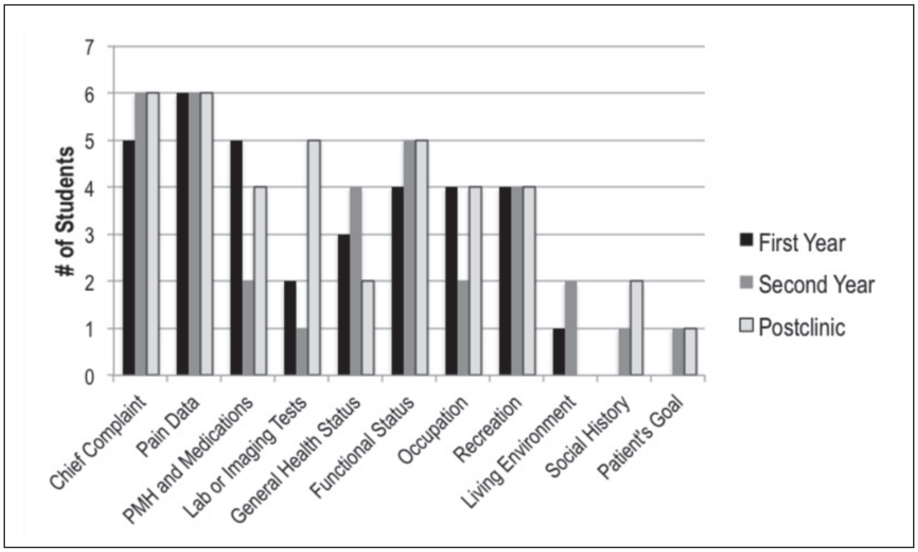

Figure 2 depicts the number of participants who obtained each type of patient interview data at each phase of the study. Data categories are derived from the *Guide to Physical Therapist Practice* 3.0.

Figure 3. Hypotheses Generated by Students

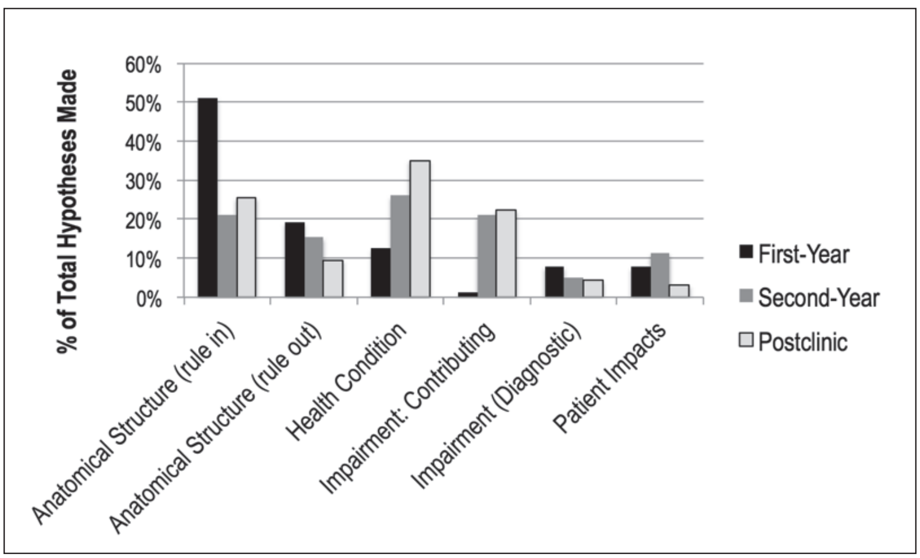

Figure 3 depicts the types of hypotheses the students formed at each phase of the study. The chart presents the percentage of total hypotheses formed in each category at a particular phase (see Table 3 for category definitions).

participation in life activities. No student consistently addressed this patient personal information, and only 1 student, Jenn, demonstrated progression toward greater attention to this patient personal information.

Hypotheses and Evaluations

During their first year, the students' hypotheses focused primarily on *anatomical structures*, either ruling in or ruling out anatomic structures. The 6 participants mentioned *anatomical structures* ruling them in as 51% of their hypotheses or ruling them out as 19% of their hypotheses. *Health condition* represented 13% of their total hypotheses. Students' hypotheses during their second-year course work were dominated by *health condition*, followed closely by *impairments as contributing factors* and then *anatomical structure*. The students' hypotheses demonstrated this same pattern following their clinical affiliations. *Patient impacts* were rarely mentioned during all phases of the study (Figure 3). During the second year, 1 student repeatedly noted *patient impacts.* Another student demonstrated a trend toward greater inclusion of *patient impacts*, but, overall, the students did not demonstrate development toward assessing the impact of the patient's condition on his or her level of disability (Table 6).

The categories of evaluations the students presented followed closely from their hypotheses. In their first year, the students named *anatomical structures* and *impairments* more than any other category (Figure 4). Following their course work, the students demonstrated a clear trend toward identifying the patient's *health condition* in their final evaluation, and most students also identified *impairments as contributing factors* to the patient's health condition. This trend of naming a *pathology* and an *impairment as a contributing factor* continued after the students' clinical affiliations. At no phase did a student's final evaluation include addressing how the health condition impacted the patient's activity or life participation. The hypotheses and assessments the students identified during the concurrent and retrospective think-aloud procedures compared with the notes they wrote during the case indicated consistency between the diagnoses the students had noted for themselves and those they had orally expressed during the think-aloud procedures.

Reasoning Strategies for Patient Evaluation

Over the course of the 3 phases of the study, the students demonstrated 5 primary patterns in their reasoning strategies. Figure 5 summarizes the reasoning strategies the students used during each stage of their education. The *trial and error* strategy was only evident during the first year. For example, Misty struggled to organize her interview and examination process. She began as most of the students did by asking for the patient's description of her pain. When she was unable to form a clear hypothesis based on the initial pain description, she asked for more details of the patient's visit with the physician, then returned to asking about the patient's pain, questioning what anatomical structures might be involved:

> *OK, I, since there's radiating as well, that might make me think um a little bit of nerve, too, because nerves have a tendency to radiate (laughs), and since it goes all the way down to the elbow, there might be um some sort of impingement um stuff and actually, I, oh it's a constant dull ache. I might ask if there's numbness and tingling at all if she's feeling any numbness and tingling anywhere?*

Table 6. Quoted Examples of Student Hypotheses

Anatomical Structure	• So now I have to differentiate between posterior deltoid musculotendinous or posterior capsule, so I would do a static test of their posterior deltoid. (Shelly, first-year) • OK, so that would lead me to believe that her muscles are probably fine and it wasn't a muscular problem. So I would probably be leaning towards maybe a capsule tear. (Kelly, first-year) • I ruled out meniscus, I ruled out ACL and PCL, and MCL LCL, which are all the ligaments on the knee. (Misty, second-year)
Health Condition	• It could be adhesive capsulitis. (Shelly, first-year) • And then some type of, that's usually a sign of arthritis. (Misty, second-year) • So, I would say that my direction at this point is that he's got a rotator cuff tendonitis of the supraspinatus, he's got a biceps tendonitis with potentially and underlying labral pathology going on. (Maya, postclinic)
Impairment: Contributing	• Any time you're walking or going down stairs if she can't stabilize her hip then her leg is rotating and the patella is going to be tracking on the lateral femur which it's not supposed to be. (Kelly, second-year) • So hip adduction in loading response, so what I'm seeing is Trendelenburg gait, and that is usually a sign of weak glute medius and then that messes up her alignment which puts excess strain on her connecting joints which would be her knee, so that might be part of something. (Misty, second-year, think-aloud) • And he has unstable scapula, and then the forward shoulders tells me it's crowding the subacromial area. … It is definitely the scapula-thoracic joint that's causing a lot of the issue. I think that's the why. (Jenn, postclinic)
Impairment (Diagnostic)	• Well the, the only thing that's stuck out to me was her abductor weakness. (Shelly, second-year) • Flat thoracic spine, so with the forward shoulders and the abducted scapula it could be tightness in the anterior shoulder musculature and weakness in the posterior, especially with the winging indicates weakness of the serratus anterior. (Cathy, post-clinic)
Patient Impacts	• Reaching up to a file cabinet like how far does she have to flex or abduct to get up to that actual file cabinet? How much it affects her functional ability that she needs to get the file or a stool or have someone else do it for her or how much it actually affects her job. (Cathy, first-year) • She really doesn't have anyone to help her around the house if she were to have any sort of knee surgery or if she needed help with the kids. She has to do it all by herself, so that could be an issue in treatment. (Jenn, second-year) • So I was asking if they were like little and he's throwing them overhead or something versus if they are older and like playing with kids means video games or something. (Misty, post-clinic)

Upon hearing that there was no numbness or tingling, she expressed some confusion. "Oh dear, (laughs) um, maybe not nerve? (laughs) But then it's radiating. Let's see: constant dull ache, since it's a constant dull ache, dang this is difficult, um." Misty's inability to form a clear hypothesis from her interview with the patient left her unsure where to start her examination process. Before beginning muscle tests, she stated: "Um, maybe do some tests? … Even though I don't have very good ideas, I guess we could do some testing. Um, um, … Hmmm, tests."

Students consistently demonstrated *reasoning about pain* across all 3 phases of the study. During the first year, the students related the patients' description of pain to possible anatomical structures that might explain the pain. Jenn expressed her thought process after hearing the patient's pain description during her first-year. "OK so now because the pain's radiating, I have a feeling there's some sort of nerve being pinched, and because of the dull achey sensation, I feel like it's something in the joint that has some sort of insult or injury." After her clinical affiliation, Maya used the patient's descriptions of the pain sensation to develop hypotheses about the patient's health condition. "At this point with the popping, the sharp twinge, I'm thinking, OK, I'm going to probably test for a labral pathology. It could be some kind of like biceps thing going on, depending on, definitely not thinking any kind of adhesive capsulitis at this point." At each stage, the students then used the hypotheses they had developed based on the pain descriptions to select further tests and measures.

Students also demonstrated *following protocol*, where they explicitly tried to remember examination forms from classes or clinic across all 3 phases, though this strategy was most prominent during the first year. During her first year, Jenn began by asking about the patient's pain description, aggravating factors, injury history, and activities. She then paused and reflected: "Um, I'm trying to think of what other subjective questions we're supposed to ask. Cuz I think I have the current the past and the social history, are there any hobbies that she does that might cause it?"

First-year students who were able to successfully use their *reasoning about pain* and *following protocol* strategies to guide their data collection demonstrated the more-sophisticated *rule-in/rule-out* strategy, while those who struggled to use the *reasoning about pain* strategy appropriately resorted to *trial and error* for the majority of their patient evaluation. For example, during her first year, Shelly used the patient's pain description to

Figure 4. Final Patient Evaluations Made by the Students

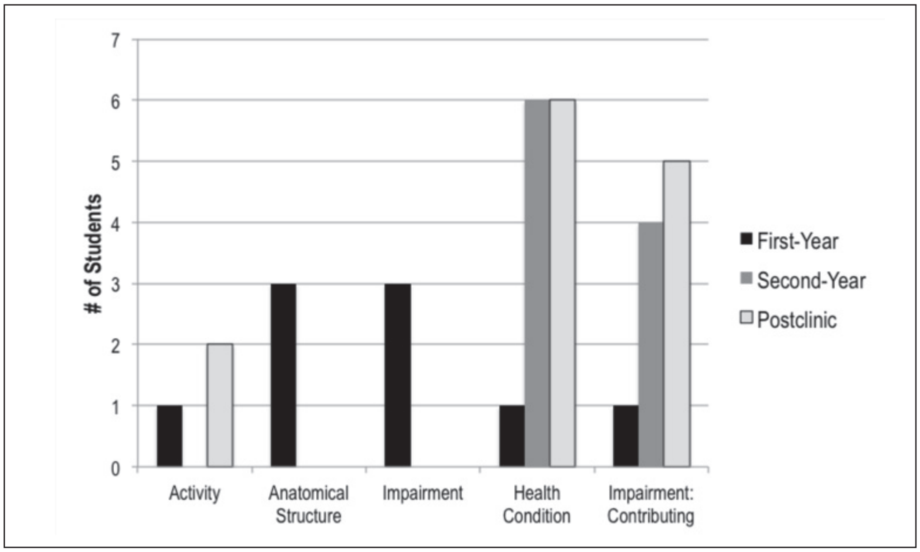

Figure 4 depicts the categories the students included in their final evaluations of the patient. The categories follow from the hypotheses formed (see Table 3 for category definitions).

Figure 5. Reasoning Strategies

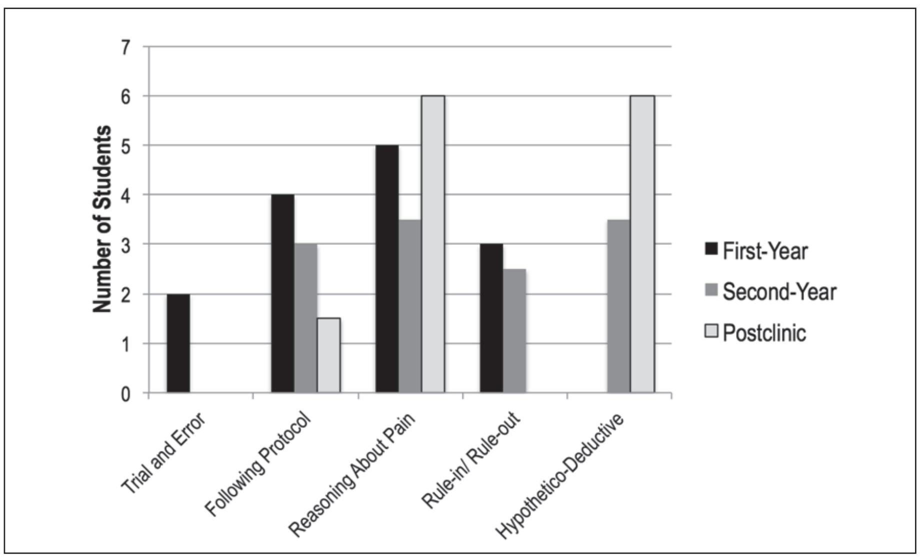

Figure 5 depicts the number of students who used each of the reasoning strategies. If a student only occasionally used the strategy it was noted as a 0.5 incidence. If the student used the strategy throughout the process it was noted as 1.0 incidence (see Table 4 for strategy definitions).

develop hypotheses about possible soft tissue involvement. After stating her hypotheses, she continued: "So I would static muscle test. To kind of rule in or out joint versus muscular versus ligamentous." Meanwhile, Misty struggled to remember and incorporate the protocol she had learned, and continued with trial and error throughout her assessment process:

> *So right now, I'm trying to think Dr. B gave us a little uh sheet that she likes to use to fill out and I'm trying to visualize the sheet and see if I (laughs) completed all of her items, she does the location, and rating the pain and morning and night, throughout the day, she, previous medications, previous tests, hobbies, anything that's happened before, Oh! So I would ask if she recalls if the pain kind of feels similar to when she did have bursitis on the right side, um or if it feels different. I know it was 10 years ago, so that uh*

During their second year, the students continued to use *reasoning about pain* to guide the start of their examinations. Once they had shifted to collecting tests and measures, some students used clearly identified hypotheses to guide and organize their process using the *hypothetico-deductive* strategy,[32] while others continued to follow *rule-in/rule-out* strategy, demonstrating less logical organization to their examination process. During this phase, several students also distinctly divided their examination into 2 stages: (1) collecting the necessary information to make the medical diagnosis, and (2) collecting the information necessary to identify the biomechanical faults contributing to the patient's health condition. For example, during her second-year, Kelly worked through the interview and then proceeded to gather information about special tests, eventually concluding that the patient had patellofemoral dysfunction. After making this assessment of the patient's health condition, Kelly inquired about the patient's posture, lower extremity alignment and manual muscle tests. She then shifted to examining functional task performance, explaining: "OK, so I'm kinda trying to see if it could be like an issue whenever she's functioning that she can't stabilize her self. Cuz she doesn't really seem to have any structural abnormalities that would put her at like higher risk for patellar tracking laterally."

Finally, following their clinical affiliations, all of the students demonstrated *reasoning about pain* and *hypothetico-deductive* strategies. For example, Jenn used the hypothetico-deductive process to integrate her evaluation of the patient's health condition and contributing factors. After she had acquired the interview information, she began the examination process by inquiring about the patient's range of motion. Upon hearing that the patient had mildly limited shoulder flexion active range of motion with pain at end range and scapular winging, she evaluated hypotheses about the anatomical structures that were affected and the contributing factors.

> *It is definitely the scapulothoracic joint that's causing a lot of the issue in why his… I think that's the why. And the what, once I get there is probably going to be the supraspinatus and biceps tendon, so I think those are irritated because the scapula-thoracic joint is not working the way it should.*

At this stage, only a few students resorted to *following protocol* when they could not remember if they had collected sufficient data.

Reasoning Errors and Omissions

As the students progressed through their coursework and clinical experiences, they made fewer analytical reasoning errors during the evaluation process on each case. During their first year, all of the students made at least 1 reasoning error in the face of uncertain information. At this stage, these errors, which took 3 primary patterns (Table 5), impacted their progress through the evaluation process. During their first year, 4 students demonstrated *jumping to conclusions*, 2 demonstrated *perseveration*, and 2 demonstrated *disregard*. The following section presents examples of each reasoning error demonstrated by the students in their first year.

During the examination portion of the case role-play, Maya demonstrated *jumping to conclusions by* drawing her conclusion of a tight joint capsule based on information about the patient's active range of motion into flexion, a necessary but not sufficient finding to make that conclusion. She explained during the retrospective think-aloud:

> *AROM, yeah um, mainly because I don't know what else to do for joint capsule and it just makes sense to move it around and see what part of it hurts. Um and to see how impinged it would be you know if they can get up very far, what, just what the motion is like, because that's pretty much all I know, how to assess the joint capsule at this point is how far can it move.*

During the first year, Shelly demonstrated *disregard* as she was unsure how to make sense of learning that the patient had experienced no relief following a cortisone injection in her painful shoulder: "So since it's, I don't know exactly what cortisone would do for it, but I uh, since it didn't help, then, that's probably not a good thing (laughs) Um, is she on any pain medication?" Kelly also demonstrated *disregard* when she was unsure what type of tests would assess ligamentous structures. During the concurrent think-aloud she expressed:

> *I don't think, I can't think of any ligament tests or ones that I would do, mainly because we haven't talked about the shoulder a whole lot, so I can't really think of anything. Um, I guess I would probably palpate and to see if the pain was localized to right around the shoulder joint or if it extends anywhere else.*

During the retrospective think-aloud, she reflected on her thought process regarding the shoulder ligaments: "I didn't suspect ligaments just because, I was even talking to somebody the other day about shoulder ligaments. I don't know how you test them, I don't know how often they you know, get injured and um, it just, I don't know, shoulder ligaments, I don't know much about them, so I just kinda ignored them (laughs)"

In additional to *disregard*, Kelly demonstrated *perseveration* during her first year as she continued to pursue a hypothesis regarding a nerve injury in the patient whose pain patterns, muscle performance testing, and sensory testing were not consistent with a nerve injury.

> *OK, then I would probably think that it was a peripheral nerve that was damage. I'm trying to think. (silence)… Well if it's a peripheral nerve and she can only move, she can only flex her shoulder against gravity then that probably means that that musculature is weak and but if that nerve is damaged it could also be causing pain in her shoulder, upper trap and into the arm. So, I think my first guess would be musculocutaneous nerve 'cuz I know that that does all the biceps and then it kinda runs into the elbow and I think maybe a little bit of the forearm not with musculature so much but it does have a sensory distribution. And also because I haven't reviewed anatomy in a while and that's like the first thing that's popping into my head. But then I would do like a dermatome test of um, let's do, the like the medial side of the arm.*

Upon hearing that the patient's sensation was intact and normal throughout the upper extremity, Kelly continued to explain her thoughts regarding a nerve injury:

> *I'm still, I think, I'm still thinking the musculocutaneous because I know that it has separate branches that do sensory so I'm thinking that maybe the lesion could be um after the sensory part of it already splits off from it. And I think that would still account for most of the problems. Um, 'cuz it does get from C6 it could be referring a constant pain and if it's still in the inflammation phase it's going to be constantly aggravated so that she would have pain at rest. And then, but whenever she's abducting and flexing it's gonna be like more impinged within the musculature so that would increase the pain higher.*

Following this train of thought, Kelly made her assessment that the patient had a musculocutaneous nerve injury with inflammation.

During the second year, 1 student demonstrated *disregard* and another student demonstrated *jumping to conclusions*. For example, after learning that the patient had normal patellar mobility, Maya jumped to a conclusion about the strength and stability of the knee as a whole, stating: "OK, if she's not hypermobile, I'm not thinking strength or stability around the knee is such the issue." Aside from these 2 students, the students did not make significant analytical reasoning errors following their coursework or clinical affiliation. These findings indicate the students' improving abilities to process and interpret typical clinical findings.

Another form of reasoning error that persisted across all phases of the study was *limited connections*, a lack of connection between any personal information collected about the patients and the impact of their condition on their day-to-day life. As described above, students were inconsistent in acquiring personal information about their patients. When they did inquire about issues such as the patient's occupation, hobbies, or living situation, this information was typically used to identify or support a mechanism of injury rather than the impact of the injury. For example, during the first year, 1 student considered the patient's occupation important only if it involved manual labor that might have caused the injury. Cathy explained her interpretation of the impact of the patient's occupation on her assessment. "If she has a job where she has to be reaching above you know, if she's a factory worker or something where she's moving a lot that could be um the reason for the problem in the shoulder, but if she is a desk, you know, sedentary worker, then you know, you have to find another reason for why the shoulder would be painful... " After their clinical affiliations, most students continued to draw on the patient's occupational information only to support their hypotheses about the type of injury or mechanism of injury. For example, after her clinical affiliation, Shelly inquired about the patient's occupation. Upon learning he was a school teacher and that he experienced shoulder pain when reaching up to write on the board, she responded: "OK, so it sounds kinda impingement-y." She did not mention the patient's occupation again during the case. Only one student (Jenn) consistently linked the patient's life factors with the impact of the health condition. For example, during her second-year, upon learning that the patient had children, Jenn commented, "Oh, little. Single mom, 8 and 10. I guess they're not that little, but. And single story home. So she really doesn't have anyone to help her around the house if she were to have any sort of knee surgery or if she needed help with the kids. She has to do it all by herself, so that could be an issue in treatment." Following her clinical affiliation, Jenn continued to make connections about the impact of the injury on the patient's occupation and hobbies. During the retrospective think-aloud, she explained why she was interested in the patient's daily activities. "Just to see if it was affecting his routine, because those are obviously, he's teaching, so it's going to interfere with everyday activities. I didn't ask how often he goes to the gym, or if he stopped, but it's obviously something he's done for a while, probably something he wants to get back to."

DISCUSSION AND CONCLUSION

Following their on-campus coursework and initial clinical affiliations, the PT students in this study demonstrated consistent progression in their abilities to assess patients' underlying biomechanical causes of injury, an important aspect of the physical therapy-specific diagnostic process. The students, however, did not demonstrate consistent development in addressing the impact of the health condition on patients' levels of participation.

Changes in Hypotheses

During their first year, students generated hypotheses primarily focused on anatomical structures. Following their second-year coursework, they shifted to identifying medical diagnoses and underlying biomechanical contributing factors. This shift toward medical diagnoses and away from basic science concepts parallels the patterns identified in the development of reasoning processes in medical students.[23] The emergence of the students' considerations for the underlying biomechanical causal factors, however, is more unique to physical therapist clinical reasoning, as most studies of physical therapist practice have highlighted the importance of a focus on movement above and beyond the medical diagnosis as part of the PTs' reasoning processes.[43,44]

Along with this shift toward evaluation of underlying biomechanical factors, a pattern of "what" and "why" reasoning emerged in the students' thought processes during the patient examination and evaluation. In this process, the students moved from primarily focusing on identifying the injured tissues (the "what") during their first year toward identifying both the health condition (medical diagnosis) and the underlying contributing factors (the "why"). This pattern is indicative of progress toward the unique reasoning processes required for physical therapist practice, as PTs must address the contributing factors and consequences of the health condition not just the condition itself.[14,15] The students' integration of this "what" and "why" thinking into the flow of their reasoning process was evident through their continued focus on both elements following their clinical affiliations, yet with less separation of the 2 processes.

Limited Attention to Patient Personal Needs

While the students demonstrated consistent progression in their analytical reasoning, most gave minimal attention to the patients' values and life context. Whereas experienced physical therapists seamlessly balance patient-centered narrative reasoning with analytical reasoning,[8,37,45] the students in this study consistently focused on analysis of biomechanical and pathological factors. While many students elicited some personal information regarding each patient, such as occupation or hobbies, many only used this information to confirm biomechanical patterns and did not make considerations for the impact of the health condition on the patient's quality of life, nor did they make use of the information in developing their interventions. The students' continued prioritization of technical and biomechanical issues may indicate that their personal frames of reference dominated over the patients' frames of reference.[22] This continued focus on mechanical and technical factors and procedures is consistent with the patterns of clinical reasoning of other intermediate-level (second-year DPT) students.[5] Although the students may be familiar with ICF and the biopsychosocial approach, they may need more familiarity with the variety of reasoning strategies entailed in order to adopt a patient-centered approach.[10] Educational strategies such as scaffolded, structured opportunities to write clinical narratives integrated within clinical experiences enable students to reflect and learn from individual patient experiences. Small group reviews of these narratives can deepen the learning process and support students in developing more patient-centered approaches to practice.[46,47] Strategies such as these narratives may support students in enacting patient-centered approaches to clinical reasoning.

Throughout their foundational science and clinical coursework and clinical affiliations, some students consistently demonstrated more concern for the patient's life factors than did others. Other authors have also noted nonhomogenous patterns of development in students' clinical reasoning, with some students demonstrating greater concern for the patient's context from early in their education, while others continue to hold more mechanical views at the completion of their entry-level education.[5] These inconsistent patterns suggest that the inclusion of patient-centered considerations may be influenced by students' backgrounds and prior experiences shaping their perspectives on care.[22,48-50]

Factors in Students' Development

Several factors may explain the students' lack of development regarding attention to the patients' personal needs. Although this study did not directly examine the curricular factors contributing to the students' clinical actions and reasoning processes, the following 2 areas warrant further investigation. First, the students may lack the cognitive capacity to integrate considerations of impairments, functional limitations, and the interpersonal dimensions of clinical reasoning.[51] Second, this lack of attention to the patient as an individual may be a result of the structure of the students' coursework, wherein interpersonal interactions and psychology are taught separately from orthopedic clinical skills, and analytical thought may be prioritized in classroom assessment.[52] While clinical experiences provide situated learning experiences critical to the development of the context-dependent skill of patient-centered clinical reasoning,[53] the pedagogical practices of clinical instructors vary widely, and these clinical instructors may not effectively support students in developing a patient-centered frame for reasoning.[54,55] Further research should address these patterns of development in relation to academic program structure.

Limitations and Further Research

This study has several limitations that should be addressed in future research. First, the study used only a single patient case simulation at each stage of the program. Given the evidence of case specificity in clinical reasoning,[56] future studies could provide a more in-depth analysis by assessing students' performance over multiple patient cases. Second was the use of a simulated patient instead of an actual clinical situation. While simulation was advantageous in allowing assessment of the students' reasoning processes prior to their instruction in hands-on patient care, it limited limits the conclusions that could be drawn regarding the students' interactions with the patient as an individual. Replication studies using a standardized patient instead of a simulated case may better address the role of students' interactive and narrative reasoning. Third, the small sample size, consisting of all female students from a single program, limits the generalizations that can be drawn. This study, however, has provided a preliminary examination of a concept not thoroughly explored in the existing literature and provides avenues for future studies. Finally, this study did not directly analyze the learning environments that contributed to the students' clinical reasoning processes. Further studies using intervention-based design can better support teaching processes that contribute to students' development of effective patient-centered diagnostic reasoning.

CONCLUSION

The development of clinical reasoning skills is a crucial yet underresearched aspect of entry-level physical therapist education programs.[5] This study has analyzed the developmental processes of 6 students enrolled in a physical therapist education program using a traditional curriculum structure. As these students progressed through their foundational coursework, clinical coursework, and initial clinical affiliations, they demonstrated physical therapy-specific development within their technical diagnostic reasoning processes. However, they demonstrated little growth with respect to concern for patients and their life context. These findings contribute to the understanding of the influence of classroom and clinical education on the development of physical therapist students' diagnostic reasoning skills.

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Appendix 1. Patient Case Scenarios

Phase 1 (First-Year) Patient Case Scenario

Brief description: Jana is a 50-year-old female complaining of left shoulder pain with a gradual onset starting 6 months ago. She cannot associate the onset with any specific incident or cause. She is complaining of difficulty with reaching upper cupboards and styling her hair.

1. Interview
    - A. Personal information
        - i. Left-handed
        - ii. Hobbies: painting, French-braiding/styling her hair
        - iii. Lives in a house with her husband (no children)
        - iv. Exercise: stationary cycling (30 min, 4 days/wk), occasional outdoor walking/hiking; no strength training
    - B. Occupation
        - i. Receptionist at a dental office
        - ii. Needs to reach file boxes on top of file cabinets
    - C. Pain description
        - i. Constant dull ache, aggravated with motion
        - ii. 7/10 with activity, reduces to 4-5/10 after an hour of rest
        - iii. Radiates from shoulder to elbow
        - iv. Affects sleep if sleeping on L side
    - D. Aggravating factors
        - i. Shoulder motion (any)
    - E. Relieving factors
        - i. Rest
    - F. PMH
        - i. Treatment for this condition
            1. 2 cortisone shots over past 3 mo (no relief of sx)
            2. NSAIDs (no relief)
        - ii. No hx of L shoulder problems
        - iii. R shoulder bursitis 10 years ago (treated w/ cortisone injections)
        - iv. Hysterectomy (7 years ago)
        - v. HTN (controlled w/ meds)
        - vi. Multivitamin and calcium supplements

2. Tests and measures
    - A. Posture
        - i. Mild kyphosis
        - ii. Forward head
        - iii. Rounded shoulders, humeral head forward in glenoid
        - iv. L scapula elevated 1 in higher than R
    - B. AROM
        - i. Scapulohumeral rhythm: L restricted scapular movement w/ scapular hiking, asynchronous
        - ii. Shoulder AROM
            1. R: WNL
            2. L: 95° flexion, 60° abd, 25° ER, 70° IR
                - a. Pain w/ all AROM, greatest w/ ER
        - iii. Cervical ROM:
            1. WNL
            2. Tight on L w/ R side-bending and L rotation
    - C. PROM
        - i. L: 100° flexion, 65° abduction, 30° ER, 80° IR
            1. Increased pain w/ each
            2. (Capsular pattern)
        - ii. Isolated Glenohumeral flexion: 70°
        - iii. L Glenohumeral accessory mobility: limited in all directions, especially inferior glide

Appendix 1. Patient Case Scenarios *continued*

D. MMT
  i. R shoulder WNL
  ii. L scapular stabilizers (middle and lower trapezius): 3/5
  iii. L serratus anterior: 3-/5
  iv. L shoulder ER: 3/5
  v. L shoulder flexion/abd (within available range): 3+/5
  vi. Abdominals: 3-/5

E. Palpation
  i. Tender L upper trapezius
  ii. Tender L arm

F. Special tests
  i. Negative impingement sign, negative speeds test
  ii. Negative drop arm/ supraspinatus sign

G. Neuro screen
  i. DTRs: 2+ throughout (WNL)
  ii. Sensation: intact throughout

Phase 2 (Second-Year) Patient Case Scenario

Brief description: Wendy is a 39-year-old female complaining of right knee pain that has been getting progressively worse over the last 2 years. She is complaining of pain with walking and a couple occasions of her knee giving way.

1. Interview
  a. Personal background info
    i. Info
      1. BMI: 27 (slightly overweight)
    ii. Hobbies/exercise
      1. Enjoyed walking 3-4 days/wk for 30-45 min (stopped 3 wks ago due to pain)
      2. Enjoyed going out dancing on weekend dates (when children are with their dad)
      3. No gym workout/strength training
    iii. Living situation
      1. Single story house with a small yard
      2. Single mother: lives w/ 2 daughters (ages 8 and 10)
      3. Helps aging parents several days/wk (they live 1 mile away)
    iv. Goals:
      1. Return to walking, stairs w/o pain, go dancing on weekends

  b. Occupation
    i. High school English teacher (involves standing, sitting at desk, walking across campus to office b/t classes, and stairs b/t classroom and office)

  c. Pain description
    i. Insidious onset
    ii. Intermittent throbbing under the patella
      1. Had fallen 3 times last 18 mo due to painful giving way
    iii. Pain rating:
      1. 7/10 descending 1 step, 9/10 descending full flight, 8/10 after walking 2 miles
      2. 0-2/10 at rest

  d. Aggravating factors
    i. Descending stairs (worst)

  e. Relieving factors
    i. Naproxen, rest, and ice

  f. PMH
    i. Treatment for this condition
      1. Naproxen (NSAID) 2-3x/week
      2. x-rays normal
    ii. Prior injuries
      1. Left rotator cuff strain 5 yrs ago
    iii. Comorbidities
      1. None

iv. Medications
1. Naproxen for pain, multivitamin and calcium supplements

2. Tests and measures
a. Posture
i. Neutral rear-foot alignment
ii. Knee neutral alignment in frontal plane (no varus/valgus); no "squinting patella"
iii. Leg length equal L-R; Q-angle = WNL
iv. Patellar positioning: WNL for medial/lateral, glide, tilt and rotation
1. NWB tracking (AROM knee extension) no obvious abnormalities

b. Functional activities
i. Gait
1. Normal sagittal plane mechanics
2. Stance phase deviations: hip add during LR on R, hip IR during MSt on R, L pelvic drop during MSt on R
3. Normal subtalar and tibial motion during stance
ii. Step down (WB on R)
1. hip IR and add w/ left pelvic drop)
iii. Sit to stand: bilateral hip add (knees come together)
iv. Poor control of pelvis during weight shift from DLS to SLS

c. AROM
i. Knee flexion: 135° B; knee extension = 0° B
ii. Hip extension = 0°; hip flexion = 100° B
iii. Hip IR = 20° B; hip ER = 40° B
iv. Hip add = 15° B; hip abd = 40° B
v. Ankle dorsiflexion = 8° B; ankle plantarflexion = 30°

d. PROM and joint mobility
i. Ankle and rear-foot mobility = WNL
ii. PROM = AROM
iii. Knee flexion end feel = soft tissue approximation
iv. Normal tibiofemoral joint mobility
v. Normal patellar mobility w/ slight pain (3/10) at EROM medial and lateral glide

e. MMT
i. Knee extension (at 30° of knee flexion) = 4/5
ii. Hip extension (gluteus maximus) = 3+/5; hip flexion = 4+/5
iii. Hip abd (gluteus medius) = 3+/5
iv. Hip ER and IR = 4-/5
v. Dorsiflexion and plantarflexion = 5/5; ankle inv/ev = 4+/5
vi. Abdominals

f. Special tests
i. Patellar compression test = slight pain w/ crepitus; negative patellar apprehension
ii. Pain w/ resisted knee extension from 20°-0° flexion
iii. Craig's test = 12°
iv. McMurray's and Apley's test = negative
v. Varus/valgus stress = negative
vi. Anterior drawer/Lachman's = negative
vii. Noble compression test = negative
g. Palpation
i. Tender over lateral patellar retinaculum (R)
h. Neuro screening
i. Lumbar and SI screen = normal
ii. Sensation normal B; reflexes normal B; SLR and PKB normal B

Appendix 1. Patient Case Scenarios *continued*

Phase 3 (Postclinical) Patient Case Scenario

Brief Description: James is a 40-year-old male complaining of left shoulder pain that has been getting progressively worse for the last 8-months.

1. Personal history
    a. Left-handed
    b. Occupation: Middle school social studies teacher (writing on the board, reaching upper shelves aggravates)
    c. Hobbies/recreation: gym 3x/wk (weight machines primarily, full circuit), tennis, and racquet ball (stopped 6 mo ago due to pain)
        i. Has been working out regularly for last 10 years
        ii. Misses social tennis games w/ friends
    d. Family: married with 2 children (ages 3 and 6), enjoys "daddy time" with kids, shoulder has been "bugging" him when playing with kids
        i. Lives in a 2-story house in the suburbs, likes to do home maintenance work but shoulder "bugs" him w/ some home care activities

2. Pain descriptions
    a. Description: popping sensation w/ overhead activities, sharp twinge w/ the pop
    b. Location: antero-superior left shoulder
    c. Rating: 0/10 at rest; 7/10 w/ repetitive overhead activity; 4/10 w/ 1 overhead motion; pain recedes over next half hour if only a couple reps, prolonged pain with longer use
    d. Aggravated by: Slight pain during gym workout, worse the next morning; pain during flexion and abd (140°-170° range); pain during writing on the white board
    e. Ease: rest, ice, NSAID helps short term

3. Physician visit
    a. X-rays: no significant findings
    b. Taking NSAID (Naprosyn) w/ no significant changes

4. PMH
    a. Borderline HTN; hypercholesterolemia; family hx of heart disease
    b. R knee ACL repair 20 yrs ago (skiing injury)
    c. Occasional LBP

Tests and measures

1. Posture
    a. Forward shoulders (L>R), abd of L scapula (9cm from SP compared w/ 5cm on R), L scapula in slight down rotation compared w/ R, prominence of L inferior angle of scapula, mild winging of B scapulae
    b. Humeral head anterior in glenoid on L
    c. "Flat" T-spine, forward head, swayback posture

2. Functional task
    a. Any overhead task excessive scapular hiking, early scapula abd and elev, poor scapular control on eccentric: no T-spine contribution
    b. Faster overhead task (mimic tennis/racquet ball serve) even greater increase in hiking and winging

3. Vitals: BP: 136/82; RR: 12, HR 72

4. AROM
    a. L shoulder flexion: 0°-175° (see abd for deviations and pain)
    b. L shoulder abd: 0°-175° with pain in 140°-170° range
        i. abd and elevation of L scapula at initiation of shoulder, and excessive scapular abd throughout ROM
        ii. Able to depress and reduce abd w/ tactile and verbal cues pain
    c. ER and IR (tested at side due to pain with abd): IR: 0°-90°; ER: 0°-90° (w/ pain)
    d. Behind the back reach: reaches to middle of R scapula (w/ pain)
    e. Limited T/S flexion and extension
    f. C/S clearing: no sx reproduction, limited R SB and L rotation w/ feeling of tightness

5. PROM
    a. Flexion and abd: 0°-180°; ~110° isolated GH motion
        i. Pain w/ these, but if humeral head stabilized
    b. Left IR and ER (tested at 90° abd) = 0°-100°; right ER and IR: 0°-80°
    c. T/S: limited accessory mobility

Appendix 1. Patient Case Scenarios *continued*

6. Muscle length tests
    a. Pec minor length: L acromion (posterior boarder) 5cm from table, R 2.5cm from table

7. MMT
    a. Shoulder flex/abd: 4-/5 L (pain); 4+/5 R
    b. Shoulder IR: 4-/5 L; 5/5 R
    c. Shoulder ER: 3+/5 L; 4/5 R
    d. Biceps and triceps: 5/5 B
    e. Serratus anterior: 3+/5 L; 4/5 R
    f. Middle and lower traps: 3-/5 L; 4-/5 R
    g. Upper traps: 5/5 B
    h. Abs: 4/5

8. Special tests
    a. Empty can/supraspinatus static test: strong and painful
    b. Speeds test: positive
    c. Neer/impingement/Hawkins-Kennedy: positive
    d. Drop arm: negative
    e. Clunk test: negative
    f. Apprehension test: negative

9. Palpation
    a. L biceps tendon tender; L supraspinatus insertion tender; tight/restricted pec minor

10. Neuro screening
    a. Sensation: WNL; reflexes: 2+ throughout; MMT: no limitations aside from shoulder (see above)

Appendix 2. Interview Guides

Phase 1 (First-Year) Interview Guide

1. Tell me a bit about yourself:
    a. How did you get interested in physical therapy?
    b. What was your experience prior to coming to Chapman?
        i. Where did you go for undergrad?
        ii. Did you do volunteer work in physical therapy?
        iii. What about work/career experience?
2. Walk me through your experience in working on the patient case:
    a. Tell me about where your thought process started (what were your first thoughts).
    b. How did you proceed through the case?
    c. How did you feel approaching this case?
3. How did you decide what questions to ask (step-by-step probing based on participant responses during the patient case)?
    a. What did you do with the responses you got to the questions?
4. How did you draw your conclusions about a diagnosis?
    a. How do you feel about your conclusion?

Phase 2 (Second-Year) Interview Guide

1. Tell me a bit about yourself:
    a. What settings/facilities have you completed your preclinicals at?
    b. What practice area of physical therapy are you most interested in working in?
2. Walk me through your experience in working on the patient case:
    a. Tell me about where your thought process started (what were your first thoughts).
    b. How did you proceed through the case?
    c. How did you feel approaching this case?
5. How did you decide what questions to ask (step-by-step probing based on participant responses during the patient case)?
    d. What did you do with the responses you got to the questions?
3. How did you draw your conclusions about a diagnosis?
    a. How do you feel about your conclusion?

Phase 3 (Postclinic) Interview Guide

1. Tell me a bit about yourself:
    a. What settings/facilities have you completed your clinicals at?
    b. How did you feel about your work on your clinicals?
    c. What practice area of physical therapy are you most interested in working in?
2. Walk me through your experience in working on the patient case:
    a. Tell me about where your thought process started (what were your first thoughts).
3. How did you proceed through the case? How did you decide what to ask (step-by-step probing based on participant responses during the patient case)?
    a. What did you do with the responses you got to the questions?
    b. How did you feel approaching this case?
4. How did you draw your conclusions about a diagnosis?
    a. How do you feel about your conclusion?