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Proposed Criteria for Assessment of Student Learning when Introducing New Manual Skills into the Entry-Level Physical Therapist Education Program

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Abstract

Purpose: Physical therapy educators are responsible for ensuring that learners demonstrate sufficient skill acquisition for safe and effective clinical practice, which includes the learners' ability to execute manual skills in a reliable and accurate manner. This study is the first attempt to assist physical therapy educators in assessing the feasibility of including new manual skills in the educational curriculum by using criteria for assessment of student learning. An example using these criteria is illustrated by a pilot experiment using the Vertical Compression Test (VCT) and Saliba Postural Classification System (SPCS), which are currently taught predominantly at the post-graduate level.
Method: Physical therapy students (SPT) were trained in the VCT and SPCS during the first year of the educational curriculum. Six SPTs and two experienced clinicians (PT) participated in the experiment. An SPT and a PT applied the VCT to subjects in their normal resting posture (PPre) and in a corrected posture (PCor). Data collection measured quantity of force, duration of application, subjects' sway, SPT/PT interpretation of test results, and students' confidence in order to determine feasibility of inclusion.
Results: There were no differences in quantified manual compression forces with a significant correlation between SPT and PT. Movements of the center of pressure indicated test subjects stood steadier during VCT performed by PT compared to SPT, but not to a clinically significant degree. Interpretation of VCT and SPCS test results was excluded as a focus of this study due to curricular limitations that influenced the study design. Student feedback indicated satisfaction with the learning experience.
Discussion: The use of the proposed criteria for assessment of student learning confirmed feasibility of inclusion of the VCT in the entry-level physical therapy education curriculum. First-year DPT students demonstrated ability to perform the VCT with appropriate technique after minimal training.

Keywords: Physical therapy; Postural alignment; Skill acquisition; Teaching manual skills; Vertical compression test

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1. Introduction

1.1. Rationale for proposed criteria for assessment of student learning

The reliability and accuracy of clinicians' manual techniques are of significant importance for many professions that use manual skills for diagnostic tests and as skilled interventions, including physical therapy, occupational therapy, massage therapy, chiropractics, and osteopathics. Students in an entry-level doctorate of physical therapy program are often novice learners related to manual techniques. They rely on various methods of feedback to develop many hands-on skills throughout the educational program, including observation of expert performance, tactile feedback as manual techniques and pressures are applied to their own bodies, feedback from peers related to manual pressures, and direct observation and correction from instructors.[1,2] Infrequently, the assessment of student learning of manual techniques are assessed in a quantifiable manner. There are limited published normative values related to the amount of force required to execute a particular manual technique with clinical effectiveness.[3–5] Clinically, there is also significant variability in what would be considered appropriate force application based on patient morphology and clinical presentation. As a result, the clinician needs to use their tactile skills to assess tissue texture and passive tissue and joint resistance when determining the appropriate amount of manual force to exert onto the patient's body. Novice learners have not yet developed these clinical tactile skills, yet instructors often utilize primarily visual assessment to gauge if a learner is demonstrating appropriate force application. The authors propose that more objective criteria can be utilized, both to increase accuracy of assessment of a student learner and also to improve the quality of the learning experience.

New manual techniques are created and validated each year, and curricular faculty must determine whether or not these techniques should be included in the entry-level physical therapy curriculum. While part of this decision-making can be based on the reliability and validity of the new manual technique, there are limitations to this as the sole decision-making criteria. First, there are some manual techniques that require the clinician to possess a level of tactile skills that come with experience in the profession, making these skills more suitable for training at the post-graduate level. It is important for curricular faculty to have criteria by which to recognize and exclude these types of manual skills from the entry-level physical therapy curriculum. This is typically determined based on knowledge of the field, but the authors propose that more objective assessment methods could be used.

The second limitation of using reliability and validity criteria to gauge whether or not to include a manual technique in the curriculum is that research in the realm of manual therapy can yield inconclusive results, for such reasons as difficulty standardizing subject demographics and that the application of manual therapy varies significantly based on patient presentation. Manual techniques such as joint manipulation and end feel assessment lack reliability even among expert clinicians,[4,6,7] which may indicate that significant variability exists in how clinicians have learned techniques that involve tactile perceptions that have not been quantified. This may indicate that quantification of manual techniques could be a useful way to study reliability.

As technology has advanced, feedback from motion capture systems and force sensors can further facilitate the development of motor learning in the classroom. Such technologies can quantify the performance of a skilled clinician, allowing for direct comparison between a novice learner's skills and those of the expert.[5,8,9] The field of chiropractics has started to develop normative values of force and speed to quantify the targeted load applied to tissues during manipulation techniques.[4] Snodgras et al.[5] reported that students demonstrated similar force applications of cervical mobilization, compared to expert physical therapists, when real-time pressure-sensor feedback was utilized. Other professions, such as endoscopy, are finding ways to quantify manual skills and allow a direct comparison between learner and expert, which also clarifies for the learner the desired target performance.[10] Instructors are encouraged to use motor learning principles when teaching novice learners new manual skills.[8,11] The available evidence indicates that instrument-assisted feedback can assist educators in determining if certain manual skills are feasible for doctor of physical therapy students to learn in a safe and effective manner in an entry-level education program, and may help distinguish which manual skills should only be taught to more advanced practicing clinicians.

The purpose of this pilot study was to develop and utilize criteria for assessment of student learning of hands-on skills in order guide faculty in more systematically analyzing whether or not a particular manual technique is appropriate to teach to entry-level doctor of physical therapy students. The authors

hypothesized that a template for research design to determine reliability and accuracy of acquiring a new manual skill would utilize the following criteria for assessment of student learning as an indication that learners can sufficiently master a given manual technique:

(1) Learners demonstrate the manual technique as accurately as experienced clinicians. This would be evident by no statistically significant difference in the data results of learners performing the technique compared to experienced clinicians performing the technique.
(2) Learners' performance of the manual technique induces the desired patient response. This measurement would be specific to the manual technique being assessed.
(3) Learners accurately interpret the results of the test or intervention.
(4) Learners report that the learning experience facilitated confidence for clinical practice.

1.2. Pilot study using the criteria for assessment of student learning to evaluate students' mastery of physical therapy manual skills related to postural assessment

In this pilot study, the authors chose to apply the criteria for assessment of student learning described above in order to conduct a feasibility study on the inclusion of the Vertical Compression Test (VCT) and Saliba Postural Classification System (SPCS) in an entry-level physical therapist education curriculum. The VCT and SPCS[12] have been taught to physical therapists via post-graduate continuing education for over 35 years, and recent research has shown that these methods are both reliable and valid.[13] Few entry-level doctor of physical therapy education programs include this education in their curriculum. Based on our teaching experiences since 2015, the skills of the VCT and SPCS can be obtained by first-year physical therapy students; however, because these skills have most commonly been taught at the post-graduate level, this could indicate that the skills require higher level diagnostic and/or psychomotor skills. The authors therefore sought to determine if student physical therapists possess the diagnostic and/or psychomotor skills to learn these techniques effectively.[13]

This feasibility study was relevant for this educational program because physical therapy educators routinely need to modify the curriculum to prepare entry-level physical therapy students with the most up-to-date, effective, and evidence-based skills in evaluation and intervention. Postural assessment and training are foundational skills in physical therapy and are utilized frequently across all practice settings and age groups. Alterations in postural alignment and neuromuscular stabilization are directly correlated with several musculoskeletal conditions[14–16] including neck pain,[17–19] shoulder impingement,[20] and thoracic and lumbar pain.[21–25] Postural interventions in physical therapy include proprioceptive retraining to restore position sense of biomechanically neutral alignment, neuromuscular retraining for stabilizer muscle groups to control against joint shear or instability, and functional training in the efficient performance of daily activities, occupational ergonomics, and recreational activities.[14,16,26,27] Despite the significance of this skill set, there is no consensus for a standardized diagnostic test to define ideal posture, nor is there consensus on standard terminology to describe posture. Consequently, this inconsistency or lack of educational guidelines can limit the efficacy of new graduates in implementing postural assessments and interventions in physical therapy practice. One historical method of postural classification is the plumb line method, introduced by Kendall, which attempts to visually assess segmental alignment by identifying deviation from pertinent landmarks as compared to a vertical reference line.[15,16,28,29] Despite being considered the gold-standard technique for postural assessment, the plumb line method has significant limitations including poor validity[30] and uncertain clinical validity in term of assessing functional stability of posture.[30,31] Bryan describes a 9.3% correct response rate when clinicians attempted to quantify subjects' lumbar lordosis, compared to the quantity calculated from the standing radiographs of the same subjects.[30] In order for a postural assessment tool to have clinical validity, it needs to be useful to the therapist in developing a movement system diagnosis, identifying impairments, and designing functional interventions. Clinical validity of the plumb line is insufficiently supported because of the limited ability to assess the entire kinetic chain between spine and lower extremities,[14,31–33] functional stability,[16,34,35] and the functional effect of spinal curvatures such as kyphosis.[33] Additionally, the relationship between the thoracic and lumbar spine is rarely considered during plumb line postural assessment and classification.

The VCT and SPCS[12] are forms of postural analysis that assess posture both visually and via manual techniques to define the biomechanical functional

efficiency of the posture. Recent evidence suggests that the VCT and SPCS are reliable and valid forms of postural assessment. Collins et al.[13] reported inter-rater reliability for the SPCS as 0.64, intra-rater reliability for the SPCS as 0.80, and validity of the VCT with significantly higher peak vertical force in a corrected posture versus a habitual posture ($p < 0.001$). The SPCS is well defined by Collins et al.,[13] who describe the complexity of postural assessment as simplified into two fundamental components of posture: (1) the sagittal plane relationship of the thoracic block compared to the pelvis, and (2) the sagittal plane tilt of the thoracic block. The most common postures of the SPCS are presented in Fig. 1 and described in Table 1.

The educational program was interested in teaching the VCT and SPC to entry-level doctor of physical therapy students because of the functional approach to postural assessment. Available evidence shows that the function of the human body is affected by posture and proper segmental alignment,[14,15,17–24,29,36] yet there is insufficient evidence to define optimal or functional posture. A functionally stable posture should be defined as both static and dynamic stability that can maintain proper segmental alignment against external forces during a functional tasks. Physical therapy practice would benefit from the use of a postural classification system to subdivide subjects into postural groupings when assessing static and dynamic neuromotor function. This would provide clinical insight about the most functionally efficient postures relative to body type and task. The applied biomechanical classification of an optimally functional posture should assess postural stability with proper segmental coordination, and a center of gravity that is securely located within the base of support, even when perceiving external forces.[3,6]

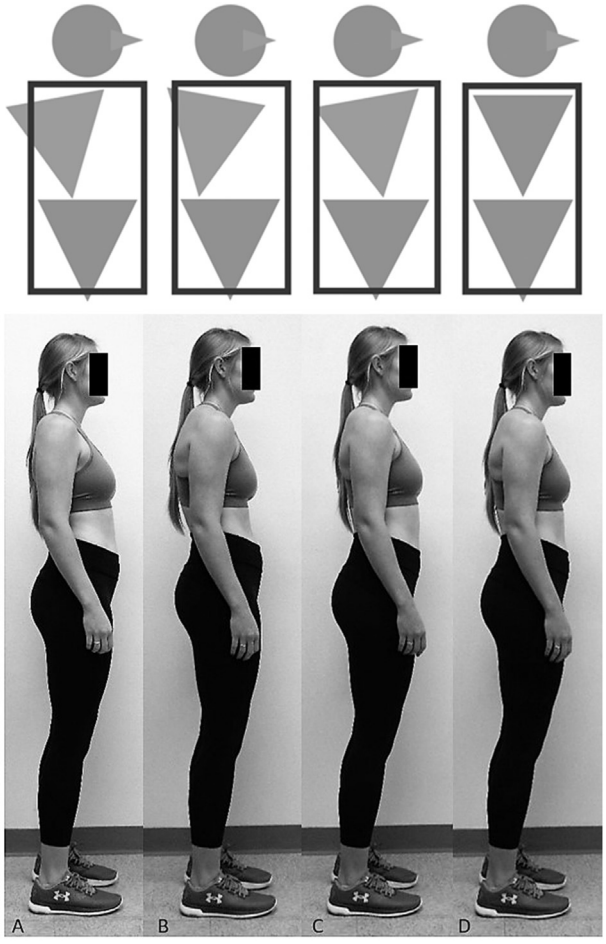

Fig. 1. Common postures described by the Saliba Postural Classification System (SPCS).[12,13] (A) Posterior/Posterior, (B) Posterior/Anterior, (C) Vertical/Posterior, (D) Vertical/Vertical.

Table 1
Saliba Postural Classification System (SPCS) descriptions of postural assessments.a.[12,13]

Common Signs of Functional Postural **Inefficiency**	Common Signs of Functional Postural **Efficiency**
Thoracic block is more posterior than the pelvis in the sagittal plane.	*Thoracic block is aligned directly over the pelvis.*
1st word: Posterior	1st word: Vertical
When a vertical load is applied, the subject will demonstrate anterior translation of the pelvis and buckling or hinging into extension near the thoracolumbar junction.	When a vertical load is applied, the vertical pressure will load through an efficient center of mass and the pelvis will not translate in either direction.
Thoracic block is more anterior than the pelvis in the sagittal plane.	*Thoracic block is in a neutral tilt.*
1st word: Anterior	2nd word: Vertical
When a vertical load is applied, the subject will demonstrate posterior translation of the pelvis and buckling or hinging into flexion near the thoracolumbar junction.	When a vertical load is applied, the subject will absorb the vertical load without the thoracic block tilting in either direction.
Thoracic block is tilted posteriorly, observed by an elevated sternum and a flare of the lower anterior ribs.	
2nd word: Posterior	
When a vertical load is applied, the subject will demonstrate buckling or hinging into extension near the thoracolumbar junction and the thoracic block will tilt further posteriorly.	
Thoracic block is tilted anteriorly, observed by a depressed sternum.	
2nd word: Anterior	
When a vertical load is applied, the subject will demonstrate buckling or hinging into flexion near the thoracolumbar junction and the thoracic block will tilt further anteriorly.	

Using the criteria for assessment of student learning, we hypothesized that the postural assessment skills of the VCT and SPCS would be feasible to teach to entry-level physical therapy students if the students:

(1) Demonstrated a quantity of force of the VCT manual techniques that was consistent with that of experienced physical therapists;
(2) Applied the VCT manual techniques in a manner that resulted in a similar patient response as that of an experienced clinician;
(3) Correctly interpreted the results of the SPCS and VCT; and
(4) Reported that the learning experience facilitated confidence with clinical practice.

2. Methods

2.1. Subjects

Six doctor of physical therapy students (SPTs) volunteered to be testers in this study. Two physical therapists (PTs) with over five years of experience using the VCT were paired with SPTs. The PTs served as a comparison group to reflect the skills of a post-graduate learner. Twelve subjects volunteered for this study. Subjects were recruited through the health sciences programs at the university. Inclusion criteria included 18−64 years of age and ability to stand for at least 30 min. Exclusion criteria included back pain and lower extremity pain or weakness, to ensure safe application of load on the musculoskeletal system. Exclusion criteria also included history of imbalance or falling, to minimize risk of atypical sway when applying a perturbation or when adjusting a subject to a foreign postural orientation. All subjects were educated on the purpose and procedures of this study, and consented through the Institutional Review Board at Human Research Protection Office, Health Science Center at University of New Mexico. Subjects and testers did not receive compensation for their participation in this study.

2.2. Education for didactic concept of VCT and manual skills practice

All physical therapy students in the cohort received a 1-h training on the VCT and a 1-h training on the SPCS during the first semester of the entry-level physical therapist education program. These trainings involved biomechanical theory, visual observation, photographic visual aids, written aids, live instructor

demonstration, peer-to-peer practice with the techniques, and instructor application of the techniques on each student. SPCS posture concepts were integrated throughout the first-year of the program, in particular when learning therapeutic exercise interventions. For example, students were instructed to attend to the relative position of the thoracic and lumbar spine when performing strengthening and stretching interventions that targeted limb musculature. For this experiment, the researchers conducted a 3-h VCT skills review at the end of the second semester, which was the same week as the experiment. All six student-testers were allowed to practice their skills for the VCT on an experienced clinician. Approximately 5 min of individualized feedback was provided to each of the six student-testers regarding technique, speed and force of application, and tactile and observational skills required to discern deviations from upright posture. The VCT training focused primarily of appropriate execution of the VCT manual technique, not on interpretation of the test results. Due to limitations in the curricular schedule, students were only provided approximately 1 h of training on interpretation of VCT and SPCS, 8 months prior to this research study. As a result, the interpretation of test results had to be excluded as a primary objective of this study.

2.3. Outcome measures for learned skills

Subjects were asked to demonstrate two postural conditions: their preferred presenting posture (PPre) and a corrected posture (PCor) where the body segments were aligned to improve postural stability. Each subject was assessed by both the PT and the SPT using the VCT in both of the testing conditions: PPre and PCor. Each tester completed two trials per subject and per posture. The testing room was isolated, which allowed for random allocation of either the SPT or the PT as initial tester. Each tester was unaware if the subject was in PPre or PCor and the tester was unable to see the subject's posture from the sagittal plane prior to application of the VCT. The order of test position (PPre vs PCor) and the order of testers (SPT vs PT) were randomly assigned for each subject. To increase consistency of subjects' posture while tested over several trials, an experienced clinician performed one the following as applicable: (a) verbally guided the subject into PPre, or (b) manually positioned the subject into PCor. The experienced clinician reassessed the subject's posture between trials to minimize any change in posture that might have occurred during the previous test. Testers provided the same verbal instructions to the subject throughout the testing process. Subjects were not provided any information about the testers' findings.

This experiment was conducted in the Gait and Motion Analysis Laboratory in the Division of Physical Therapy at University of New Mexico. Each experimental trial was videotaped with a digital camera (Handycam, Sony Co, Tokyo Japan). A pressure mat (HR Mat Tekscan Inc, Boston, MA) calibrated to the subject's bodyweight and contact area was used to quantify the subject's postural control. The pressure mat captured the magnitude and distribution of pressure from the external forces of the testers' hands to the subjects' feet. The data capturing was completed when the tester verbally identified perception of subject's sway or perturbation during the VCT load application. Photographs of each subject in PPre and PCor was captured at the first frame of the digital video data in order to diagnose the subjects' posture based on the SPCS postural classification.

2.4. Analysis of outcome measures

Criterion #1: Magnitude of force applied during testing trial was analyzed to compare manual techniques during VCT. Manual compression forces were defined as the amount of kilograms the tester applied to the subject's shoulders up to the point when the tester perceived a postural deviation. Duration was defined as the amount of time from start of force application to the verbal alert that postural deviation had occurred. Fig. 2 describes how the testing variables are defined by using the force trajectory from the pressure sensor. The initial data point at the Y axis ideally correlated to a force that equaled the subject's bodyweight. If this did not correlate, it was determined a reflection of a slight mechanical delay during data capture, resulting in a slight discrepancy in the timing of the tester's hand placement and the beginning of capturing. In such trials, the slope of the force curve was extrapolated into the negative X axis to capture the delay and add to the test duration.

Criterion #2: To quantify subjects' response during VCT, area and direction of sway, distance and direction traveled by subjects' center of force (COF), variability in distance traveled by COF, and weight-bearing percentage between right and left were assessed using the pressure data captured by the floor sensor.

Criterion #3: The accuracy of the interpretation of VCT test results was assessed by an interview immediately following the completion of an experimental

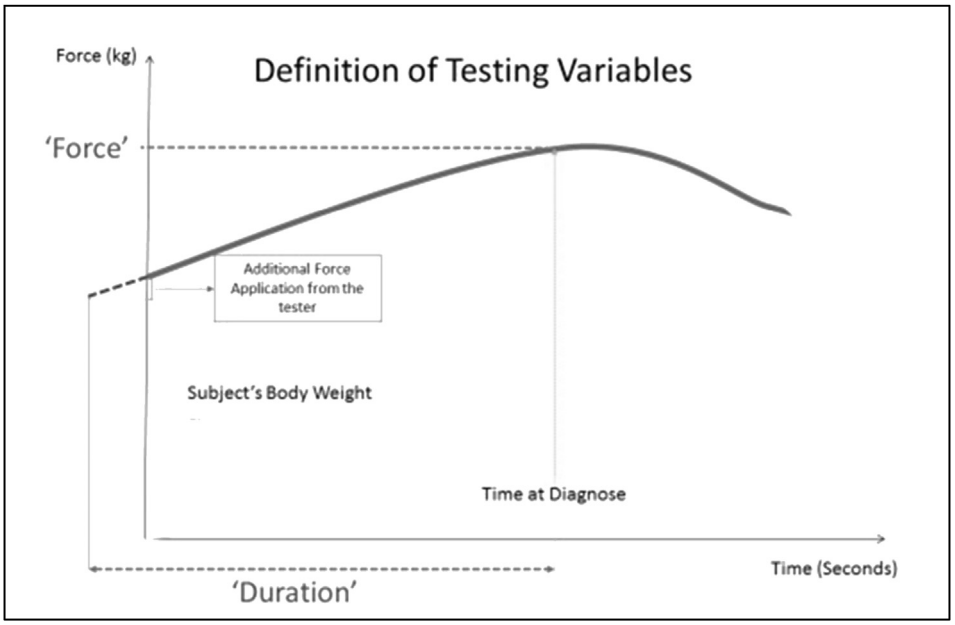

Fig. 2. Determination of Manual Compression Forces and Trial Duration. Peak force was captured at the moment that the SPT or PT reported a postural deviation ("Diagnose"). End point duration utilized this same moment of reported postural deviation, and occasionally had to be extrapolated to the left of the Y axis at a point where the force equaled the subject's body weight, indicating that no vertical force from the SPT or PT had yet been applied.

trial, at which time each tester was asked to identify the trial during which the subject demonstrated a more efficient posture. The accuracy of the interpretation of SPCS test results was assessed following data collection, using still photographs of each subject in PPre and PCor (n = 24). The primary investigator and each SPT independently assessed all photographs and used the SPCS to give each photograph an SPCS postural classification. The primary investigator compiled the SPCS classifications to compare each student's responses to the lead researcher's responses. Matches were tallied for each student, resulting in a ratio of each student's accuracy in classifying the posture compared to an experienced clinician.

Criterion #4: Each student-tester received an individualized feedback session with the primary investigator after data collection was complete. During this session, the primary researcher reviewed the videos and the pressure mat data of the student and their paired experienced clinician, to observe similarities and differences in test performance. Graphic and numerical data were compared, as well as videotapes of performance. Students were then asked to complete a brief qualitative questionnaire about their confidence and satisfaction following this experience. This questionnaire is provided in Table 2.

For the two quantified data, statistical analyses were applied for following research hypotheses: (1) The manual techniques of the force and duration of applying VCT would not be significantly different between SPT and PT; (2) Subjects' postural stability during VCT will reflect biomechanical characteristics of better posture by increasing stability regardless of testers' level of experience. For the first hypothesis, Paired t-tests and Pearson Produce Moment Correlations were used to compare manual techniques between SPT and PT. For the second hypothesis, Analysis of Covariance was applied for each testing variable in order to examine whether the slope of increasing postural stability in subjects would be equal between SPT and PT and the adjusted mean of postural stability

Table 2
Questionnaire on student confidence and satisfaction with the learning experience.

1. What are your thoughts about the ease of clinical application of the Vertical Compression Test compared to standard postural alignment using a plumb line?
2. Do you feel that the review session improved your clinical skills related to postural assessment? Why or why not?
3. Do you feel that the feedback session improved your clinical skills related to postural assessment? Why or why not?
4. Please feel free to share your thoughts regarding this workshop here.

would be the same between SPT and PT. The statistical tests were conducted with SPSS (SPSS v26 IBM Co.). Alpha level was set at 0.05.

3. Results

3.1. Criterion #1: comparison of quantification of manual technique

Quantity of force application until postural deviation was perceived, both in PPre and in PCor, indicated that the research hypothesis (SPT and PT are the same) was supported (PPre: $p = 0.15$, 95% CI -9.62, 1.67 kg); PCor: $p = 0.98$, 95% CI -4.99, 4.88 kg). Duration of force application until postural deviation was perceived, both in PPre and PCor, indicated that the research hypothesis (SPT and PT are the same) was supported (PPre: $p = 0.73$, 95% CI -1.81, 2.51 sec); PCor: $p = 0.15$, 95% CI -0.93, 5.28 sec). Pearson's Correlation Coefficient indicated statistically significant correlation between SPT and PT in amount of force application until postural deviation was perceived (PPre: $r = 0.71$, $p = 0.01$; PCor: $r = 0.77$, $p < 0.01$). Duration of force application did not show a significant correlation between SPT and PT (PPre: $r = 0.54$, $p = 0.07$; PCor: $r = -0.21$, $p = 0.52$), however the quantified difference was not clinically meaningful (See Table 3 and Fig. 3).

3.2. Criterion #2: comparison of subjects' response during VCT

The results of ANCOVA revealed significant interaction of duration and distance were attributed to level of experience of the tester ($p = 0.001$, $p = 0.002$). There were main effects between preferred and corrected postures in COP movements in the AP direction ($p = 0.034$) as well as decreased rear-foot bearing of the left foot ($p < 0.01$). There was also a main effect of posture in duration to peak vertical forces ($p = 0.016$). It indicated that the corrected posture showed improved functional stability regardless of the speed of external force application. Fig. 4 presents comparative force data for SPT and PT combined trials in PPre and PCor, and shows that the majority of subjects were able to accept higher compressive loads in the corrected posture compared to the presenting posture. All other testing variables showed no significant difference.

3.3. Criterion #3: student interpretation of test results

Because there were limitations in training the students effectively for this portion of the study, the data on student interpretation of test results was excluded from this study. The authors recommended future study of novice versus experienced therapists' interpretation of VCT and SPCS test results.

3.4. Criterion #4: student confidence and satisfaction

Students' comments on the questionnaire included the following:

- *"… it was not difficult to learn and perform the VCT … as compared to the plumb line test … just looking at someone's posture does not always tell the entire picture of what and where a possible postural dysfunction may exist."*
- *"… seeing the video of myself performing the test demonstrated what I need to work on to perform the test better."*
- *"The more feedback I receive, the more and more the test makes sense to me. I know now to make adjustments to my own posture during application of the VCT, and also for the general purpose of creating more efficient posture for myself."*
- *"The VCT is simple and intuitive, the verbal cues to give the subject are straight forward and easy to remember."*

Table 3
Statistical Analysis for force and duration (SPT/PT).

		PPre	PCor
Paired *t*-test	Force	$t = 1.545$, $p = 0.15$ (−9.62, 1.67)[a]	$t = 0.02$, $p = 0.98$ (−4.99, 4.88)[a]
	Duration	$t = 0.35$, $p = 0.73$ (−1.81, 2.51)[a]	$t = 1.54$, $p = 0.15$ (−0.93, 5.28)[a]
Correlation	Force	$r = 0.71$, $p = 0.01$	$r = 0.77$, $p < 0.01$
	Duration	$r = 0.54$, $p = 0.07$	$r = -0.21$, $p = 0.52$

Abbreviations: SPT, Physical therapy student; PT, Experienced clinician; PPre, presenting posture; PCor, corrected posture.
[a] 95% confidence interval.

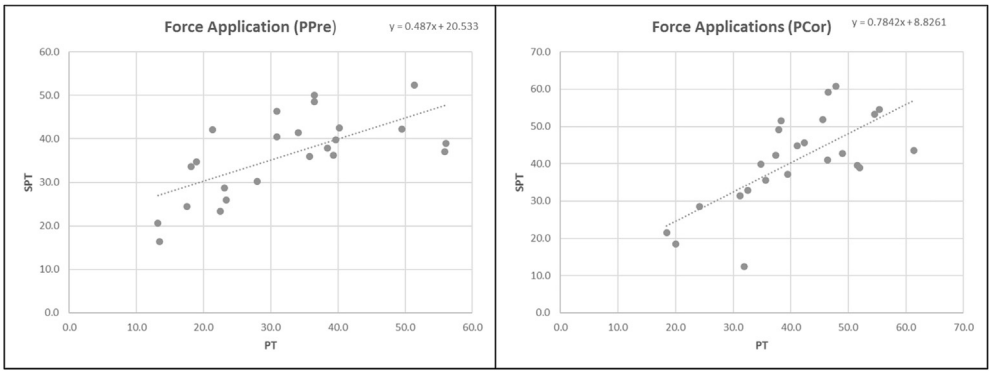

Fig. 3. Pearson's Correlation Coefficient between physical therapy student (SPT) and experienced clinician (PT) for force application (in kilograms) in presenting posture (PPRe) and corrected posture (PCor).

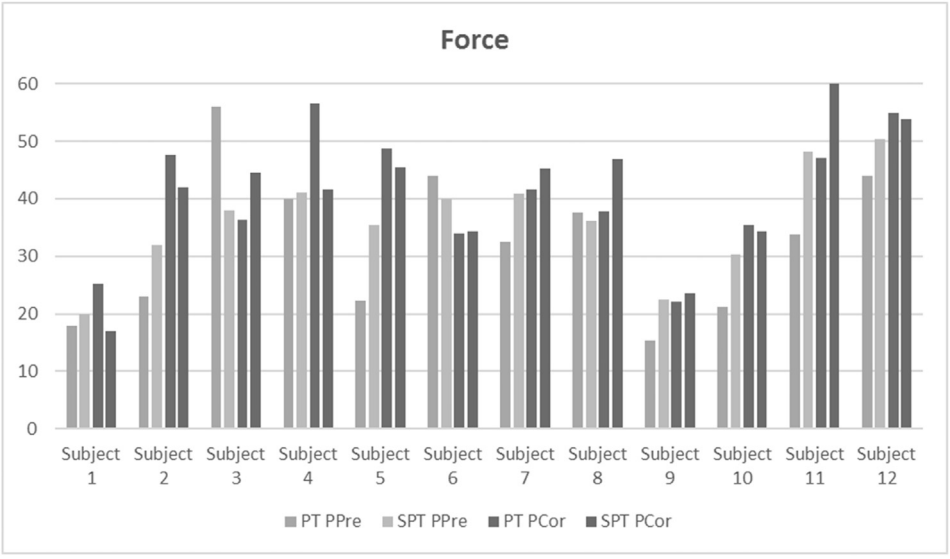

Fig. 4. Comparative force data (in kilograms) of physical therapy student (SPT) and experienced clinician (PT) during presenting posture (PPre) and corrected posture (PCor).

- *"It was great to see that even though I was nervous that I was pretty consistent and for the most part my results were somewhat compatible with [the PT's]. I wasn't sure if I had performed the test accurately, but this was reassurance that I was on the right track."*
- *"I believe that the VCT is a clinical test that is easy to perform and it is more helpful than the visual assessment of posture, both because the visual assessment can be more challenging when assessing patients with different body types, and it can transition into a more objective test-retest that can demonstrate improved posture to the patient after a posture correction."*

4. Discussion

4.1. Criteria for assessment of student learning using quantification of the learners' application of manual clinical tests and interventions

Establishing reliability, validity, and accuracy of clinical tests and interventions is imperative in evidence-based physical therapist practice. Physical therapy educators are responsible for conducting feasibility studies when implementing new skills in the entry-level curriculum. In order to critically analyze the feasibility of implementing a new skill, the educator must analyze both the practical benefits of the

new skill and its durability. For durability, this study provides an insightful template for educators. When considering a new manual skill to implement in the entry-level physical therapy curriculum, the educator is encouraged to use the 4 proposed criteria in order to assess if novice learners are able to learn the technique effectively:

(1) Incorporate the use of data to quantify the manual technique. Comparative results that show no statistically significant difference in learners performing the technique compared to experienced clinicians performing the technique would support inclusion in the educational curriculum;
(2) Incorporate the use of data to show that learners' performance of the manual technique induces the desired patient response;
(3) Assess the learners' ability to accurately interpret the results of the test or intervention; and
(4) Collect student feedback to ensure that the learning experience enriches student learning and builds confidence for clinical practice.

Advanced technologies allow clinicians and educators to quantify manual techniques and patients' responses during a particular clinical test or intervention. The authors believe that the use of technology is an objective way for educators to make decisions regarding curricular content.

This was a pilot study conducted without power analysis, and to the authors' knowledge, this is one of the few studies that has compared physical therapy students' execution of a special test to that of an experienced physical therapist by quantifying the accuracy of a manual technique. Quantification of other special tests and manual techniques could be beneficial areas for further study in the physical therapy profession. The use of technology in this manner could have several benefits to an education program, including improving instructors' assessment of students' accuracy with manual techniques, providing feedback to instructors on the efficacy of their teaching methods, and aiding in the development of learner confidence by using visual data to enhance the learning experience.

4.2. Significant findings related to feasibility of VCT and SPCS inclusion

The results of this study indicated that the quantity of force applied during the VCT by students was comparable to that of an experienced PT. This indicated accuracy not only in the amount of load applied but also accuracy in a student's ability to apply the load at a vertical angle. This was true both for subjects in a normal resting posture (during which postural deviation might occur under very little load) and in a corrected posture (during which there may not be any signs of postural deviation and therefore higher vertical load application). The duration of force application represents the speed at which the load is initiated, increased, and then terminated. The results of this study indicated that an SPT will apply the VCT for a duration of time clinically comparable to that of an experienced PT. This shows that first-year doctor of physical therapy students, with minimal training, are able to execute the manual skills of the VCT appropriately. As with any special test, there are inherent risks of performing the test incorrectly such as stressing symptomatic tissue.[15] The VCT has not yet been studied in a symptomatic population, however, the authors believe that the risks of performing the VCT incorrectly are minimal because the applied load is minimal. The benefits of learning the VCT and SPCS are an asset to clinical practice because they can help a physical therapist teach a patient the faults in their posture and strategies to achieving a more functional posture.[12,13]

The statistical results of subjects' response to VCT indicated that an experienced PT performed the VCT more accurately than an SPT by applying less deviated forces, yet it should be noted that the quantified difference in postural sway may not be clinically meaningful (<0.5 cm difference). These results bear implication for future study using real-time feedback methods to improve students' accuracy with the manual technique. The use of comparative feedback using graphical and visual data and video analysis was effective at enhancing students' confidence in their accuracy of test performance and should be considered as a teaching and learning method for the VCT, SPCS, and other special tests in the physical therapy curriculum. Students enjoy comparing their performance to that of an experienced clinician, especially when learning a new hands-on technique.

4.3. Limitations

Curricular limitations prevented sufficient application of criterion #3, test interpretation, in this study design. Interpretation of VCT and SPCS was only taught for 1 h in the curriculum, eight months prior to the study. In contrast, students received additional training on the manual aspect of the VCT immediately

prior to the study. There was also insufficient quality of videography, causing both the lead researcher and the students to have difficulty making an effective SPCS hypothesis due to lower-resolution photographs. Of note, test interpretation is a clinical reasoning variable and is only indirectly linked to the application of the manual technique. Therefore, the authors believe that the feasibility of the inclusion of the manual aspect of the VCT was illustrated effectively in this study. There were also mild technical limitations in providing instrumental feedback, which resulted in less than 1 s of time-delay in capturing force sensors and audio data.

This was a pilot study with a small sample size. Despite this and the limitations presented above, the authors hope that the efforts made in quantifying manual skills are noteworthy to all educators, students, and clinicians to provide better educational experiences. All entry-level physical therapy education programs are challenged with providing measurable feedback to students. Many medical technologies are available for both clinical and educational settings, and they should be considered as a way to provide feedback, especially for manual techniques which are difficult to teach and assess in a quantifiable way.

4.4. Conclusions

This pilot study provides insightful criteria for assessment of student learning of hands-on skills, which the authors believe is a useful template for educators to conduct systematic investigation on feasibility of implementing new psychomotor skills into an educational curriculum. The proposed criteria are especially useful for educators if the skill in question was historically taught at the post-graduate level. Suggestions for future study include a longitudinal investigation of physical therapy students' learning across a variety of psychomotor tests and measures. This could include analysis of students' retention of skills from year one through year three of the curriculum, or comparing students' performance when different forms of feedback are provided. Learning theory suggests that duration of retention is an indicator of learning,[37] therefore the authors suggest that the criteria for future studies also include an item #5 related to re-testing of manual skills after several months duration of time to assess for retention.

This study investigated the feasibility of implementing the VCT and SPCS into an entry-level physical therapist education curriculum by utilizing the proposed criteria for assessment of student learning to assess students' mastery of the manual techniques. The SPCS and VCT are reliable postural assessment tools and are used many clinicians because of the biomechanical features that define functional postural stability, however they are commonly taught at the post-graduate level. Our findings related to criterion items 1, 2, and 4 support the feasibility of implementing the VCT in the entry-level curriculum. Students demonstrated competence by performing comparable manual techniques and inducing similar patient responses as those of an experienced clinician, and also indicated that the learning experience improved their clinical skills confidence. Further study is warranted on criterion #3 related to students' accuracy of interpretation of VCT and SPCS test results, as the educational curriculum allowed for limited training opportunity within this study design.

Ethical approval

Ethical approval has been granted from the University of New Mexico Health Science Center Internal Review Board for research involving human subjects (date, reference number).

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Vicky Saliba Johnson has a 50% interest in the Institute of Physical Art, an international post professional continuing education organization that awards continuing education units to physical and occupational therapist. She does not have any financial interest in this research, nor will the outcomes have any financial effect on any of her business interests.

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