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The Effect of Real Time Auditory Feedback during Palpation of a Simulated Lumbar Spine in the Education of Physical Therapy Students

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Abstract

Objectives: Health professionals recognize simulation training as a beneficial educational technology. Physical therapy programs are slow to embrace this technology as a high-impact teaching tool, leaving students to learn in a more traditional, subjective manner with minimal objective feedback. Simulation technologies used during student physical therapist (SPT) education have been limited to mobilization and palpation. When learning palpation skills, SPTs rely mainly upon subjective feedback from peers and instructors to verify correct skill performance. Simulation with real time auditory feedback (RAF) as a teaching device may eliminate this bias. We hypothesize that the utilization of real-time audio feedback (RAF) during simulated lumbar spine palpation will improve the speed and accuracy skills of SPTs.

Methods: This was a mixed design study. The effect of RAF on palpation speed and accuracy during use of a simulated lumbar spine was examined in 30 SPTs. All were randomly assigned to one of three groups: RAF/tactile feedback training, tactile feedback training, and a control without training. A mixed ANOVA was performed to determine if any interaction effect existed within and among groups.

Results: No significant interaction effect was found for actual accuracy (p=0.90), self-perceived accuracy (p=0.30), or speed (p=0.46). Within group difference for actual accuracy was found significant with those training with RAF. (p=0.038) Accuracy for those training with RAF/tactile feedback was 55% higher than those who trained with tactile feedback alone.

Conclusion: In this study, SPTs improved their palpation accuracy using RAF and a lumbar spine palpation simulator. Those who received RAF during training outperformed their peers by 55% greater accuracy. These findings support the use of RAF and simulation technology in education to enhance palpation skill development for SPTs.

Keywords: Lumbar spine; Motor skills; Simulation training; Students; Spinal palpation

Introduction

Health professionals worldwide have introduced the use of educational technology and simulation-based training to help students and clinicians learn and practice skills in a controlled learning environment [1]. This form of education allows trainees to practice their skill while posing no risk to patients. Physicians, physician assistants, and nurses have produced research showing its benefit [2-4]. Physical therapists (PTs) have not fully embraced this technology as a high-impact teaching tool, leaving students to learn in a more traditional, subjective manner with minimal objective feedback. Simulation technologies used during student physical therapist (SPT) education have been limited to mobilization and palpation [5,6]. Palpation is performed by PTs to identify anatomical sites, point tenderness, swelling, muscle tremors and/or fasciculations [7]. When learning palpation skills, SPTs rely on subjective feedback from peers and instructors to verify correct skill performance. Simulation with real time auditory feedback (RAF) as a teaching device may eliminate this bias.

Studies have used a simulated spine model and force plate to assess a PT's ability to perform graded mobilizations on an L3 vertebrae [8,9]. Consistency of mobilization was determined using a force plate placed beneath the PT or by measuring the amplitude of displacement during the technique [8,9]. Both studies focused on the consistency of a mobilization, a measure which is often subject to instructor bias. Visual-perceptual learning was found to be an ineffective tool when analyzing inter-therapist reliability during graded mobilization [9]. Since previous studies have demonstrated variability between therapists performing mobilizations, focus may now be redirected towards how feedback from a simulated model can assist in SPT education.

Studies have also examined the effects of objective feedback on SPTs performing posterior to anterior (PA) mobilization of the spine [5,6]. A table synchronized with load cells was used to measure the force, amplitude, and oscillation of each mobilization performed. If the students performed a mobilization outside of a preset baseline, both auditory and visual feedback was provided [6]. A study comparing the use of objective feedback versus no feedback on the mobilization of C7 found that objective feedback improved students' ability to provide consistent mobilizations [5]. Sheaves et al. found that self-controlled feedback was more beneficial than constant or intermittent feedback when comparing the timing of feedback during mobilization of L3 [6].

Although these studies demonstrated educational technology can provide SPTs objective feedback, their sole focus was mobilization consistency. When learning, SPTs develop their own approach to palpation [7]. Palpation for pain has been proven to be significantly more reliable than palpation for segmental restrictions in the spine [10]. To date, the effect of RAF during palpation of a simulated lumbar spine by SPTs has not been examined. The purpose of this study is to determine if the use of RAF during simulated lumbar spine palpation can improve the efficiency of a SPT's palpation skills. We hypothesize that the utilization of RAF during simulated lumbar spine palpation will improve the speed and accuracy of a SPT's palpation skills.

Methods

Study design/participants

This mixed design study investigated the effect of RAF on SPTs during palpation of a simulated lumbar spine. The Biomedical and Health Sciences Institutional Review Board (IRB) of New York Institute of Technology approved this study. Thirty student volunteers were recruited from the PT program through IRB-approved flyers. Each received a consent form outlining the study description, inclusion criteria, and potential risks to read and sign prior to participation. Prospective participants were excluded if any of the following existed: formal training in passive accessory motion testing of the spine, sensory deficits of the thumb or fingers, any limitation in wrist/hand mobility, major musculoskeletal injuries to the upper extremities, inability to understand and sign the consent form, pregnancy, or other health related issues that may interfere with any individual's ability to safely participate in this study.

Equipment

A newly developed lumbar spine palpation simulator (LSPS) provided RAF. Software and hardware components were developed and fabricated through an interdisciplinary, grant-funded collaboration of the Department of Physical Therapy and School of Engineering at New York Institute of Technology. A sculpted torso was primarily constructed of dense foam covered by a double layer of ultrathin neoprene. A 3D printer was used to create each vertebral segment that was suspended along a wooden base via springs and posting hardware. One central and two lateral pressure sensors (Phidgets, Calgary, AB, Canada) were inserted between the larger and smaller components of each segment. When PA force was applied to the spinous or transverse processes of each segment, the corresponding sensor would relay a message to a coupled laptop (Apple, Cupertino, CA, USA) and provide an appropriate RAF response. The software was developed to run in one of two modes: a testing mode and a training mode. Responses in the testing mode were limited to “ouch” or “okay”, while responses in the training mode provided appropriate anatomical information for each segment (i.e. L5 central PA, L5 unilateral PA left, L5 unilateral PA right). All RAF was based on precision and force direction rather than magnitude.

Two-point discrimination

A co-investigator (CI) performed two-point discrimination testing of the thumb and fingers to establish the sensory integrity of each participant. The CI tested the palmar aspect of the thumb, index and middle finger bilaterally with a standard two-point discrimination wheel (Fabrication Enterprises, Elmsford, NY, USA). It has been shown to provide both valid and reliable measures for sensory testing [11]. After providing instruction and a demonstration for each individual with their eyes open, the CI asked them to close their eyes and proceeded to test their sensory acuity. Testing began with an 8 mm distance between prongs and proceeded accordingly to a lesser distance based on response. Individuals were excluded from the study if their minimal discriminatory distance was greater than 5 mm.

Main study

This pretest-posttest study occurred over three consecutive days. All 30 participants were randomly assigned to one of three groups. One group received training with RAF, one received training without RAF, and the control received no training. Testing was performed on the first and third days while training occurred on the second day. Because all SPTs were novices to passive accessory spinal motion testing, the principal investigator (PI) provided daily, consistent, and uniform instruction regarding the LSPS's use. A brief palpation demonstration was also provided using a single vertebral segment accompanied by the PI's scripted dialogue. The participants were instructed to provide PA pressure over the spinous process and each transverse process with enough force to blanch the nailbed of their palpating digit. A lumbopelvic model was utilized to orient each student to the bony landmarks used in posterior lumbopelvic palpation.

Testing (Days 1 and 3)

Each participant was told that the goal of the test was to palpate and provide PA pressure on all three bony eminences for each of the five lumbar vertebrae. The participants had 30 minutes to complete the task. Each student began standing at the lower end of the torso with their thumbs placed over the simulated posterior superior iliac spines (PSIS). The SPTs were told they could not ask for any assistance once the testing began and that verbal notification was required after task completion for timing purposes. The PI began each session with a countdown of “3-2-1–begin” in order to synchronize the timing device. Upon PA pressure of each lumbar spinous process or transverse process, the participants received a RAF response of either “ouch” or “okay” from the computer. A chart depicting the L1-L5 vertebrae was provided for each participant to document the RAF response at the perceived corresponding vertebral level and bony eminence. Three boxes from left to right were provided per lumbar level. Participants were asked to document with an “X” indicating a response of “ouch” and an “O” indicating a response of “okay.”

Training (Day 2)

Only the RAF and tactile groups received a training session. The goal of training was to palpate and provide PA pressure on all three bony eminences for each of the five lumbar vertebrae. Each participant began in the same position standing at the lower end of the torso with thumbs placed over the simulated PSISs and had 30 minutes to complete the task. The SPTs were told they could not ask for any assistance once the testing began and that verbal notification was required after task completion for timing purposes. The PI began each session with a countdown of “3-2-1–begin” in order to synchronize the timing device. Upon PA pressure of each lumbar spinous process or transverse process, the RAF group received an audio response from the computer confirming both the vertebral level and force direction (i.e. “L5 central PA” for the spinous process, “L5 unilateral PA left” for the left transverse process, and “L5 unilateral PA right” for the right transverse process). Neither group was required to document their training experience.

Statistical analysis

Data were analyzed using SPSS (Version 22.0, IBM, Armonk, NY, USA). The influence of RAF on speed and accuracy for all three groups was analyzed using a 3-way repeated-measures analysis of variance to determine if an interaction effect existed from pretest to posttest. Post hoc analysis for the group factor on actual accuracy was further studied by performing multiple comparisons using the Bonferroni correction. Simple t-tests were performed to compare the mean outcomes of speed and accuracy for RAF and tactile groups during training. The assumption of equality of variance for each was checked using the Levene's test.

Results

Participant demographics

Demographic data for all 30 SPTs are listed in Table 1.

		RAF n=10 (mean ± SD)	Tactile n=10 (mean ± SD)	Control n=10 (mean ± SD)	p-value
Age (years)		23.9 ± 2.22	23.3 ± 2.77	24.8 ± 0.71	0.4
Gender	**Male**	6	2	6	
	Female	4	8	4	
Year in Program	**1st**	9	8	8	
	2nd	1	2	2	
*Significant at an alpha level of <0.05					

Table 1: Participant demographics.

Two-point sensory discrimination

Outcomes of two-point sensory discrimination of all participants with respect to which hand was tested are presented in Table 2.

	Left (mean ± SD)	Right (mean ± SD)	p-value
Thumb (mm)	3.87 ± 0.63	4.00 ± 0.64	0.38
Index Finger (mm)	3.77 ± 0.86	3.63 ± 0.76	0.18
Middle Finger (mm)	3.97 ± 0.67	3.70 ± 0.75	0.06
*Significant at an alpha level of <0.05			

Table 2: Sensory discrimination.

Comparison of pretest and posttest among three groups

A repeated measures analysis of variance was used to determine if the interaction effect was significant for accuracy and speed within and among groups in pretest and posttest sessions. Results revealed the interaction effect was not significant for actual accuracy (p=0.90), self-perceived accuracy (p=0.30), and speed (p=0.46) (Table 3).

Measure	Effect	p-value
Actual Accuracy (%)	Group	0.038*
	Session	<0.001*
	Interaction	0.9
Perceived Accuracy (%)	Group	0.9
	Session	<0.001*
	Interaction	0.3
Speed (ms)	Group	0.31
	Session	0.22
	Interaction	0.46

*Significant at an alpha level of <0.05

Table 3: Results of 2 × 3 repeated measures ANOVA on accuracy and speed.

Neither the impact of gender nor year in program as covariates was found to be significant. The difference of the participants' actual accuracy by "group" was significantly different between those who received RAF training and those who received tactile feedback (p=0.042). Those who received RAF showed 16% more accuracy in their palpation (Table 4).

	(I) Group	**(J) Group**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	Upper Bound
Bonferroni	Audio Feedback	Tactile Feedback	0.160*	0.061	0.042	0.005	0.315
		Control	0.117	0.061	0.198	-0.039	0.272
	Tactile Feedback	Audio Feedback	-0.160*	0.061	0.042	-0.315	-0.005
		Control	-0.043	0.061	1	-0.199	0.112
	Control	Audio Feedback	-0.117	0.061	0.198	-0.272	0.039
		Tactile Feedback	0.043	0.061	1	-0.112	0.199
*The mean difference is significant at the 0.05 level.							

Table 4: Post Hoc analysis for the factor "Group" on actual accuracy.

Comparison of training between two groups

Based on the statistical results, the group receiving RAF took more time for palpation (465,027 ms) than the group receiving only tactile feedback (177,207 ms) (p=0.036). The RAF group also showed higher actual accuracy (93.3%) than the tactile group (38.0%) (p<0.001) (Table 5).

	RAF (mean ± SD)	**Tactile (mean ± SD)**	**p-value**
Speed (ms)	465,027 ± 358,397.02	177,207 ± 135,080.83	0.036*
Actual accuracy (%)	93	38	<0.001*
*Significant at an alpha level of <0.05			

Table 5: Training between groups.

Discussion

Although no significant interaction effects were found among the groups, all individuals improved in actual accuracy from pretest to posttest regardless of training experience. The narrow timeframe between testing may have contributed to a positive learning effect for all participants [11,12]. Motor learning theories suggest skill acquisition can be achieved through simple experiences of observation and repetition [13,14]. To obtain benefits from observation, the observer must attend to relevant information, retain the information, have the ability to use the information, and have the desire to imitate the modeled action [13]. The SPTs were granted exposure to all four of these components which could account for their rapid skill development [15-17].

The use of RAF during training and between training sessions resulted in significantly greater accuracy scores when compared to participants receiving only tactile feedback. RAF provided immediate information regarding accuracy and enhanced psychomotor learning for skill acquisition during segmental vertebral palpation. Practice and feedback are the two most important factors considered during motor learning of a new skill [18]. Chang et al. demonstrated improvements in accuracy when performing glenohumeral joint mobilizations on a simulator for groups receiving visual feedback compared to control groups without visual feedback [19]. Winstein notes augmented external feedback, known as knowledge of results, provides participants with necessary information regarding performance success. This enables the correction of improper skill performance and stimulates the problem-solving to develop the correct method of execution [20]. Knowledge of results allows the student to independently recognize the factors necessary for accurate skill performance. The use of RAF may afford valuable feedback following classroom instruction of a new skill providing SPTs with individualized and objective knowledge of their performance accuracy.

The use of RAF during segmental vertebral palpation training improved the accuracy of palpation while simultaneously demonstrating a decreased speed of performance. The acquisition and retention of a motor skill accuracy occurs more readily than the speed at which it can be performed. Hikosaka et al. described an accuracy-speed dual memory model in which accuracy is the first element improved while learning a new skill. Further improvements are made in terms of performance speed with continued practice after accuracy has plateaued, regardless of hours required to improve accuracy to such a point [21]. The same plateau in accuracy and procedure time was noted when using visuospatial and perceptual feedback on medical students performing a procedure on a simulated renal artery [22].

These findings suggest that SPTs would be able to increase the speed of performance of vertebral spinal palpation with additional practice.

Both the RAF and tactile training groups showed a positive learning effect, which may have been caused by increased exposure time, repetition, and practice time in a simulated setting. As a technical skill, palpation requires continued practice and repetition, though SPTs achieve and maintain competency in palpation at varying speeds [23-25]. Groups provided with a training day may have developed a greater understanding of the simulation model due to increased exposure time. Participants in the RAF group may have taken longer to complete all palpations secondary to receiving auditory feedback regarding their palpation accuracy. Increased practice time in a simulated setting allows learners to efficiently correct mistakes and deliberately practice technical skills in a safe, non-threatening environment [25]. Since the study was performed in a closed environment, students were able to comfortably develop palpation skills without real-life stressors. Through exposure, learner-centered simulation encounters allow the achievement of technical proficiency prior to application in the clinical setting [26]. Body mechanics and procedural efficiency improve with increased exposure time, which is associated with increased expertise [27,28]. For this reason, simulation training may improve patient outcomes and may be more effective than clinical training alone [25, 29-31].

Limitations

A potential limitation of this study includes the sensitivity of the LSPS. The model was programmed to state “ouch” or “okay” when palpated correctly, however, if a student did not receive RAF, he or she often used greater pressure to elicit a response leading to sensors being triggered for a different spinal segment. The students often misinterpreted the response of the model and believed that they had successfully palpated the correct spinal segment. This particular event occurred frequently during the study and likely skewed the participants’ perception of their performances.

Another limitation which may have caused results to vary was the chosen hand-placement of each participant. Although palpation of each transverse process was demonstrated using one hand, many participants opted to utilize a two-hand approach, keeping one hand in contact with each of the transverse processes at all times. As a result, simultaneous pressure on the transverse processes may have triggered a central PA sensor, as opposed to a unilateral sensor. Additionally, the use of neoprene as the material surrounding the lumbar spine model may have led to unintentional activation of the incorrect sensor if the neoprene was pulled too taut, despite proper hand placement and palpation.

One final limitation of this study entails the documentation of findings by the subjects. Participants varied in documentation technique as several students chose to fill out the sheet immediately after receiving an RAF response, while others chose to fill out the sheet after palpating several spinal levels. This led some participants to make mistakes in their documentation, without realizing their errors.

Conclusion

In this study, SPTs were able to improve their palpation skills through the use of RAF and a LSPS. Those who received RAF during training outperformed their peers by 55% greater accuracy. These findings support the use of RAF and simulation technology in education to enhance palpation skill development for SPTs. Future research is suggested to further examine the benefits of this technology and its integration in physical therapy classrooms.

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